Image Extraction, Segmentation, & Recognition

Vol. 4550

PROCEEDINGS OF SPIE
SPIE—The International Society for Optical Engineering

Image Extraction, Segmentation, and Recognition

Tianxu Zhang
Bir Bhanu
Ning Shu
Chairs/Editors

22–24 October 2001
Wuhan, China

Sponsored by
SPIE—The International Society for Optical Engineering
Huazhong University of Science and Technology (China)

Cosponsored by
Université de Bordeaux III (France)
University of Pennsylvania (USA)
Wuhan University (China)
Chinese Academy of Sciences
Beijing Institute of Environmental Features (China)
Tsinghua University (China)

Supported by
National Natural Science Foundation of China
Ministry of Education of China

Published by
SPIE—The International Society for Optical Engineering

Volume 4550

SPIE is an international technical society dedicated to advancing engineering and scientific applications of optical, photonic, imaging, electronic, and optoelectronic technologies.

The papers appearing in this book compose the proceedings of the technical conference cited on the cover and title page of this volume. They reflect the authors' opinions and are published as presented, in the interests of timely dissemination. Their inclusion in this publication does not necessarily constitute endorsement by the editors or by SPIE. Papers were selected by the conference program committee to be presented in oral or poster format, and were subject to review by volume editors or program committees.

Please use the following format to cite material from this book:

Author(s), "Title of paper," in *Image Extraction, Segmentation, and Recognition*, Tianxu Zhang, Bir Bhanu, Ning Shu, Editors, Proceedings of SPIE Vol. 4550, page numbers (2001).

ISSN 0277-786X
ISBN 0-8194-4278-X

Published by
SPIE—The International Society for Optical Engineering
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone 1 360/676-3290 (Pacific Time) • Fax 1 360/647-1445
http://www.spie.org/

Copyright© 2001, The Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is $15.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923 USA. Payment may also be made electronically through CCC Online at http://www.directory.net/copyright/. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/01/$15.00.

Printed in the United States of America.

Symposium Committees

Symposium Honorary Chairs

Benjamin W. Wah, University of Illinois/Urbana-Champaign (USA)
Bo Zhang, Tsinghua University (China)
Thomas S. Huang, University of Illinois/Urbana-Champaign (USA)

Symposium Chairs

Anil K. Jain, Michigan State University (USA)
Deren Li, Wuhan University (China)
Jun Shen, Université de Bordeaux III (France)

Program Committee

Chairs

J. K. Udupa, University of Pennsylvania (USA)
Tianxu Zhang, Huazhong University of Science and Technology (China)

Members

Bir Bhanu, University of California/Riverside (USA)
J. M. Carazo, Universidad Autónoma de Madrid (Spain) and Universidad de Malaga (Spain)
Yair Censor, University of Haifa (Israel)
Dingchang Chen, China National Space Administration
Jacky Desachy, Université Paul Sabatier (France)
Jufu Feng, Peking University (China)
Weikang Gu, Zhejiang University (China)
Pheng-Ann Heng, Chinese University of Hong Kong
Bruce Elliot Hirsch, Temple University (USA)
Thomas S. Huang, University of Illinois/Urbana-Champaign (USA)
Anil K. Jain, Michigan State University (USA)
Dehua Li, Huazhong University of Science and Technology (China)
Deren Li, Wuhan University (China)
Jian Liu, Huazhong University of Science and Technology (China)
Zhiyong Liu, National Natural Science Foundation of China
Siwei Lu, Memorial University of Newfoundland (Canada)
Henri Maître, Ecole Nationale Supérieure des Télécommunications (France)
Stephen J. Maybank, University of Reading (UK)
Yuichi Ohta, University of Tsukuba (Japan)
Heping Pan, CSSIP (Australia)
Sharatchandra Pankanti, IBM Thomas J. Watson Research Center (USA)
Jiaxiong Peng, Huazhong University of Science and Technology (China)

Maria Petrou, University of Surrey (UK)
Jun Shen, Université de Bordeaux III (France)
Xubang Shen, Xian Institute of Microelectronics Technology (China)
Zhenkang Shen, National University of Defense Technology (China)
Pengfei Shi, Shanghai Jiaotong University (China)
Zhongzhi Shi, Institute of Computing Technology (China)
Tieniu Tan, National Key Laboratory of Pattern Recognition (China)
Zheng Tan, Xi'an Jiaotong University (China)
Jun Tian, Rice University (USA)
Qingxi Tong, Institute of Remote Sensing Applications (China)
Jayaram K. Udupa, University of Pennsylvania (USA)
Benjamin W. Wah, University of Illinois/Urbana-Champaign (USA)
Friedrich M. Wahl, Technische Universität Braunschweig (Germany)
Jinxue Wang, SPIE—The International Society for Optical Engineering (USA)
Patrick S. Wang, Northeastern University (USA)
Runsheng Wang, National University of Defense Technology (China)
Yuanmei Wang, Zhejiang University (China)
Chengke Wu, Xidian University (China)
Guangyou Xu, Tsinghua University (China)
Jie Yang, Shanghai Jiaotong University (China)
Jingan Yang, Hefie University of Technology (China)
Jingyu Yang, Nanjing University of Science and Technology (China)
Xingliang Yin, The Second Academy (China)
Baozong Yuan, Northern Jiaotong University (China)
Yehoshua Y. Zeevi, Technion—Israel Institute of Technology
Bo Zhang, Tsinghua University (China)
Tianxu Zhang, Huazhong University of Science and Technology (China)
Guangxi Zhu, Huazhong University of Science and Technology (China)
Yaoting Zhu, Huazhong University of Science and Technology (China)
Zhenfu Zhu, The Second Academy (China)

Organizing Committee

Chairs

Mingyue Ding, Huazhong University of Science and Technology (China)
Qingxi Tong, Institute of Remote Sensing Applications (China)
Yaoting Zhu, Huazhong University of Science and Technology (China)

试读结束，需要全本PDF请购买 www.ertongbook.com

Conference Committee

Conference Chairs

Tianxu Zhang, Huazhong University of Science and Technology (China)
Bir Bhanu, University of California/Riverside (USA)
Ning Shu, Wuhan University (China)

Program Committee

Dingchang Chen, China National Space Administration
Junbin Gao, University of Southampton (UK)
Le Guo, Northwestern Polytechnical University (China)
Jian Liu, Huazhong University of Science and Technology (China)
Jiaxiong Peng, Huazhong University of Science and Technology (China)
Zheng Tan, Xi'an Jiaotong University (China) and City University of Hong Kong

Introduction

In 1998, the first SPIE International Symposium on Multispectral Image Processing and Pattern Recognition was held at the Huazhong University of Science and Technology, Wuhan, China. That conference was a great success, at which scientists, engineers, and graduate students from more than 20 countries and regions made about 130 presentations of their new research results concerning image processing and pattern recognition. Of the more than 130 papers, nine were selected to be published in a special issue on image processing and pattern recognition of the *International Journal of Pattern Recognition and Artificial Intelligence*.

Today, the Second SPIE International Symposium on Multispectral Image Processing and Pattern Recognition has attracted 500-odd high-level papers from 24 countries and regions in the world. The scale is larger than before and more departments are represented. It is our belief that this symposium is bound to score even greater successes. As one of the SPIE series of academic symposium, it will be held once every other year.

Feature extraction and image segmentation are the foundation for computer vision. Image analysis and human face recognition are the research topics for both dynamic image analysis and biometrics. These topics have long since aroused great interest of numerous researchers; more than 60 papers are included in this volume. These proceedings of the conference on Image Extraction, Segmentation, and Recognition, of the Symposium on Multispectral Image Processing and Pattern Recognition, will promote academic exchange among researchers of different countries and regions, and the deepening of the relevant investigations and applications.

We extend our thanks to all authors and committee members present for their contributions to the success of the said symposium!

Tianxu Zhang
Bir Bhanu
Ning Shu

Contents

ix *Symposium Committees*
xi *Conference Committee*
xiii *Introduction*

KEYNOTE PAPER

1 **Statistical learning theory and its application to pattern recognition (Keynote Paper)** [4550-02]
L. Zhang, Anhui Univ. (China); B. Zhang, Tsinghua Univ. (China)

SESSION 1 IMAGE SEGMENTATION I

9 **Kernel method in pattern recognition and classification (Invited Paper)** [4550-03]
J. Gao, Univ. of Southampton (UK)

19 **Task-guided segmentation and its application in real-time IR ship recognition** [4550-07]
Y. Wang, N. Zeng, T. Zhang, Huazhong Univ. of Science and Technology (China)

24 **Algorithm of segmentation for virtual endoscopy** [4550-04]
X. Liu, H. Lu, National Lab. of Pattern Recognition (China)

28 **Automatic segmentation of video object plane based on object tracking and matching** [4550-05]
L. Shi, Z. Zhang, H. Wang, Shanghai Univ. (China)

34 **Texture identification and image segmentation via Fourier transform** [4550-08]
M. Zou, D. Wang, Institute of Electronics (China)

40 **Image segmentation based on local Fourier coefficients histogram** [4550-09]
F. Zhou, J. Feng, Q. Shi, Peking Univ. (China)

SESSION 2 EDGE DETECTION AND FEATURE EXTRACTION

46 **Pyramidal edge detector based on adaptive weighted fuzzy mean filters** [4550-31]
Z. Wang, D. Wang, W. Wang, X. Xu, Shanghai Jiaotong Univ. (China)

52 **Using wavelet for filtering speckle and extracting edge from ocean SAR image** [4550-46]
Z. Guo, Institute of Remote Sensing Application (China); G. Lu, Xiamen Univ. (China)

57 **Application of stochastic heuristic search method to edge extraction in noisy images** [4550-32]
J. Han, L. Guo, Northwestern Polytechnical Univ. (China)

63 **Edge extraction from multispectral images and density analysis of superdimensional spectral space** [4550-34]
N. Shu, Wuhan Univ. (China)

67 **Model of extraction and representation of spatial knowledge using Hough transform** [4550-42]
J.-R. Tapamo, Univ. of Natal (South Africa)

73 **Using opponent correlation functions to recognize color texture** [4550-44]
M. Al-Rawi, J. Yang, Shanghai Jiaotong Univ. (China)

79 **Study of sparse features in image recognition** [4550-45]
J. Sun, Q. Zhuo, W. Wang, Tsinghua Univ. (China)

85 **Corner detection algorithm based on multifeature** [4550-38]
K. Zhang, J. Wang, Q. Zhang, Institute of Optics and Electronics (China)

SESSION 3 IMAGE SEGMENTATION II

91 **Novel intelligent multi-agent image segmentation method with confidence estimate (Invited Paper)** [4550-17]
T. Zhang, F. Wu, Huazhong Univ. of Science and Technology (China)

103 **Analysis of image segmentation aimed for sense matching** [4550-11]
X. Liao, Z. Cao, Huazhong Univ. of Science and Technology (China)

109 **Variational approach to image segmentation** [4550-14]
Y. Tian, H. Xu, J. Liu, Huazhong Univ. of Science and Technology (China)

115 **Improved adaptive genetic algorithm and its application to image segmentation** [4550-15]
L. Wang, T. Shen, Beijing Institute of Technology (China)

121 **Automatic threshold estimation for gradient image segmentation** [4550-16]
T. Zhang, X. Wang, Y. Wang, Huazhong Univ. of Science and Technology (China)

127 **Feature encoding for color image segmentation** [4550-18]
N. Li, Nanjing Univ. of Aeronautics and Astronautics (China); Y. F. Li, City Univ. of Hong Kong

SESSION 4 FACE IMAGE RECOGNITION

132 **Dynamic gesture recognition using PCA with multiscale theory and HMM** [4550-30]
H. Wu, A. Sutherland, Dublin City Univ. (Ireland)

140 **Face recognition based on eigenfeatures** [4550-19]
P. Quintiliano, Departamento de Polícia Federal (Brazil); A. Santa-Rosa, Univ. de Brasília (Brazil); R. Guadagnin, Univ. de Católica de Brasília (Brazil)

146 **Multiscale local discriminatory feature representations for automatic face recognition** [4550-20]
B. Hong, C. H. Chen, S. Tang, Univ. of Massachusetts/Dartmouth (USA)

154 **Face detection based on multi-information** [4550-29]
C. Wu, J. Zhou, Z. Bian, Tsinghua Univ. (China)

160 **Face recognition with multiple eigenface spaces** [4550-21]
M. Jiang, G. Zhang, Z. Chen, Huazhong Univ. of Science and Technology (China); Z. Zhang, Central China Normal Univ.

165 **Face detection by quadratic Gabor filter on feature inertia surface and its verification by modified retinal model** [4550-22]
L. Ma, Y. Zhang, South China Univ. of Technology

171 **Video-based face verification** [4550-23]
W. Hong, H. Ai, L. Zhuang, G. Xu, Tsinghua Univ. (China)

176 **Efficient approach to Chinese phoneme mouth-shape recognition** [4550-24]
X. Zhong, S. Ma, B. Zhang, Tsinghua Univ. (China)

182 **Multipose face recognition in a complex background** [4550-25]
C. Zhu, R. Wang, National Univ. of Defense Technology (China)

188 **3D face recognition system using cylindrical hidden-layer neural network: spatial domain and its eigenspace domain** [4550-26]
B. Kusumoputro, M. Y. Pangabean, L. F. Rachman, Univ. of Indonesia

196 **Detection and tracking of facial features based on stereo video** [4550-28]
Q. Wu, G. Xu, L. Zhuang, Tsinghua Univ. (China)

202 **Fast hierarchical knowledge-based approach for human face detection in color images** [4550-27]
J. Jiang, J. Gong, G. Zhang, R. Hu, Huazhong Univ. of Science and Technology (China)

SESSION 5 FEATURE EXTRACTION II

211 **New estimation of Hurst parameter for texture analysis** [4550-41]
Y. Li, J. Peng, Huazhong Univ. of Science and Technology (China)

217 **Local window approach to detect line segment based on line model in low-quality image** [4550-43]
J. Gao, J. Yang, M. Ren, H. Sun, Nanjing Univ. of Science and Technology (China)

221 **Approach to extracting the human body framework from a color image** [4550-39]
Y.-S. Chen, S.-S. Chiu, Yuan Ze Univ. (Taiwan)

228 **Adaptive window-size selection approach for feature extraction in texture analysis** [4550-35]
W. Sheng, C. Xu, Air Force Radar Academy (China); J. Liu, Huazhong Univ. of Science and Technology (China)

234 **Feature extraction and recognition of harbor contour** [4550-33]
Y. Li, J. Peng, Huazhong Univ. of Science and Technology (China)

239 **Optimal K-L transform method for feature extraction** [4550-36]
J. Yang, J. Yang, Nanjing Univ. of Science and Technology (China)

245 **Feature analysis: support vector machine approaches** [4550-37]
Y. Shi, T. Zhang, Huazhong Univ. of Science and Technology (China)

POSTER SESSION

252 **Automatic thresholding of gray-level images using two-dimensional Bayes discrimination rule** [4550-50]
H. B. Guan, Shanghai Jiaotong Univ. (China); G. R. Xuan, Tongji Univ. (China); Y. C. Bai, Shanghai Jiaotong Univ. (China)

258 **Novel algorithm for automatic detection of faces and facial features in color images** [4550-51]
Y. Xing, Z. Tan, S. Wu, Xi'an Jiaotong Univ. (China)

264 **Mahalanobis-distance image segmentation based on two-dimensional histogram** [4550-52]
X. Zhang, H. Zuo, Y. Yu, Tianjin Univ. (China)

270 **Method of image segmentation based on fringe pick-up** [4550-53]
J. Zhang, H. Wang, Y. Wang, J. Liu, Beijing Institute of Technology (China)

276 **Edge detection based on order morphology filtering** [4550-55]
B. Ye, J. Peng, Huazhong Univ. of Science and Technology (China)

281 **Linear feature extraction for infrared image** [4550-56]
T. Li, Y. Wang, Z. Chen, R. Wang, Beijing Univ. of Aeronautics and Astronautics (China)

287 **Level set methods and image segmentation** [4550-57]
D. Wang, H. Yu, Z. Tang, Tsinghua Univ. (China)

295 **Using segmentation for precision tracking** [4550-58]
W. Yang, J. Li, Z. Shen, National Univ. of Defense Technology (China)

302 **Split-and-merge segmentation using relation stable state** [4550-59]
M. Ren, J. Yang, H. Sun, Z. Tang, Nanjing Univ. of Science and Technology (China)

309 **New segmentation algorithm for detecting tiny objects** [4550-60]
H. Sun, J. Yang, M. Ren, J. Gao, Nanjing Univ. of Science and Technology (China)

313 **Real-time approach to recognizing the human face in poor-quality video** [4550-61]
Z. Chen, G. Zhang, M. Jiang, Huazhong Univ. of Science and Technology (China)

319 **Corner detection method based on wavelet transform** [4550-62]
X. Peng, C. Zhou, M. Ding, Huazhong Univ. of Science and Technology (China)

324 **Feature extraction for magnetic domain images of magneto-optical recording films using gradient feature segmentation** [4550-63]
Q. Zhu, X. Zou, X. Wang, H. Li, X. Shen, Huazhong Univ. of Science and Technology (China)

328 **Fast algorithm for 2D entropic thresholding of image segmentation** [4550-64]
J. Su, J. Tian, J. Liu, Huazhong Univ. of Science and Technology (China); Z. Sun, Institute for Technological Physics of Jinhang (China)

334 **Automatic segmentation of overlapping and touching chromosomes** [4550-65]
Z. Yuan, X. Chen, Tsinghua Univ. (China); R. Zhang, Sun Yat-Sen Univ. of Medical Sciences (China); C. Yu, Tsinghua Univ. (China)

340 **Application of some valid methods in cell segmentation** [4550-66]
X. Chen, C. Yu, Tsinghua Univ. (China)

试读结束，需要全本PDF请购买 www.ertongbook.com

345 **New second-order difference algorithm for image segmentation based on cellular neural networks (CNNs)** [4550-67]
S. Meng, Y. Mo, Shanghai Univ. (China)

350 **Study and application of extraction method of fundus image parameters** [4550-69]
M. Lu, D. Gao, East China Univ. of Science and Technology

358 **Rapid segmentation method of vehicle license plate based on knowledge** [4550-70]
X. Yuan, J. Li, L. Xia, Southeast Univ. (China)

363 **Scalable face synthesis algorithm** [4550-71]
Y. Ran, Tsinghua Univ. (China); Q. Liu, Wuhan Univ. of Technology (China); Q. Liao, Tsinghua Univ. (China)

368 **Technique for roof-edge detection based on morphological method** [4550-72]
L. Zhu, F. Zhou, Beijing Univ. of Aeronautics and Astronautics (China)

374 **Extraction and estimation of facial expression by means of wavelet decomposition and active shape template** [4550-73]
Y.-S. Chen, H.-P. Kuo, Yuan Ze Univ. (Taiwan)

380 **Generation method for face image based on model** [4550-75]
J. Zhang, G. Zhang, Huazhong Univ. of Science and Technology (China)

388 **Self-adaptive segmentation for infrared satellite cloud image** [4550-76]
P. Wang, J. Xue, Z. Liu, Tianjin Univ. (China); H. Liu, G. Tang, National Meteorological Ctr. (China)

394 **Adaptive approach to small-object segmentation** [4550-78]
T. Shen, L. Wang, Beijing Institute of Technology (China)

401 *Author Index*

Statistical learning theory and its application to pattern recognition

Ling Zhang* and Bo Zhang
Sate Key Lab of Intelligent Technology and Systems
Tsinghua University, Beijing, China
*Artificial Intelligence Institute, Anhui University, Anhui, China

ABSTRACT

The problem of pattern recognition is formulated as a classification in the statistic learning theory. Vapnik constructed a class of learning algorithms called support vector machine (SVM) to solve the problem. The algorithm not only has strong theoretical foundation but also provides a powerful tool for solving real-life problems. But it still has some drawbacks. Two of them are (1) the computational complexity of finding the optimal separating hyperplane is quite high in the linearly separable case, and (2) in the linearly non-separable case, for any given sample set it's hard to choose a proper nonlinear mapping (kernel function) such that the sample set is linearly separable in the new space after the mapping. To overcome these drawbacks, we presented some new approaches. The main idea and some experimental results of the approaches are presented.

Keywords: statistic learning, pattern recognition, support vector machine, covering algorithms

1. INTRODUCTION

Vapnik presented a new statistical learning theory recently [1]-[5]. The theory deals with the rather general problem, i.e., the problem of choosing the desired dependence on the basis of empirical data. The pattern recognition, either speech, image or language recognition, etc., can be regarded as a classification problem. It is involved in the general problem above, learning from data. The general model of the pattern recognition can be stated as follows. For simplicity, we only consider the two-class classification problem.

Given the training set

$$K = \{(x^1, y^1), \ldots, (x^m, y^m)\}, \quad x^i \in R^n, y^i \in \{-1, 1\}.$$

Where the probability distribution function $F(x, y)$ is unknown. The problem is to construct a learning algorithm that minimizes the probability of a classification error based on the given data.

Now we consider the learning problem in neural networks.

A given sample set

$$K = \{(x^i, y^i), i = 1, 2, \ldots, m\}, \quad y^i \in \{1, -1\}. \tag{1}$$

Assume a three-layer feed-forward neural network N, x is its input, y is its output. A set of actuation functions of neurons is as follows.

Image Extraction, Segmentation, and Recognition, Tianxu Zhang, Bir Bhanu, Ning Shu,
Editors, Proceedings of SPIE Vol. 4550 (2001) © 2001 SPIE · 0277-786X/01/$15.00

$$y = f\left(\sum_{j=1}^{n} w_j x_j - \theta\right),\ f(x) \text{ is a sign function.} \qquad (2)$$

The learning problem in neural networks is to construct a procedure for choosing from this set an approximating function using the samples such that if vector x^i belongs to the first class $y^i = 1$ and if vector x^i does not belong to the first class $y^i = -1$. So the learning principle of neural networks is the same as that of the general learning problem (or classification problem).

Vapnik constructed a class of learning algorithms called support vector machine (SVM) to solve the classification problem by using the optimal separating hyperplane. The SVM theory can briefly be stated as follows: If a given sample set is linearly separable, the learning problem is to find the optimal (maximal margin) separating hyperplane by using some optimization technique; If a given sample set is linearly non-separable, the original input vectors x are mapped in high dimensional feature space by a kernel function such that the images of the input vectors in the new space are linearly separable. Then, the problem can be solved in the same way as the linearly separable case. These ideas provide a new tool for solving real-life problems. But there are drawbacks in the SVM algorithms. First, in the linearly separable case, the computational complexity is generally quite high for finding the optimal separating hyperplane. In the linearly non-separable case, for any given sample set it's generally hard to find the proper kernel function. Our research works on these issues and some of its applications are discussed below.

2. FINDING THE OPTIMAL SEPARATING HYPERPLANE

When the sample set K is linearly separable, the goal of SVM is to construct a hyperplane that separates vector x into two classes and has the maximal margin. Vapnik transferred the problem into a quadratic optimization problem, i.e., finding the saddle point of a Lagrange function by using Lagrange multipliers method. But generally, to find the optimal separating hyperplane with the maximal margin, its computational complexity is quite high based on the Lagrange multipliers method. In order to improve the computational complexity, the problem was transformed as follows. From formulas (1) and (2), we know that if the sample set is linearly separable then the following inequalities have solutions (see [6] for more details).

$$\sum_{i=1}^{n} (w_i x_i^k - \theta) y^k > 0$$

$$w = (w_0, w_1, \ldots, w_n), \qquad w_0 = \theta$$

$$x(k) = (x_0^k, x_1^k, \ldots, x_n^k), \qquad x_0^k = -1$$

$$c^k = x(k) y^k$$

Where $x^k = (x_1^k, x_2^k, \ldots, x_n^k)$ is the input vector.

$w = (w_0, w_1, \ldots, w_n)$ is the weight-threshold vector.

Let

$$C = \begin{bmatrix} c^1 \\ c^2 \\ \cdots \\ c^m \end{bmatrix}$$

Then, the learning problem, i.e., finding the weight-threshold vector w, of neural networks under training sample set K can be equivalently transferred into that of finding the s of the following inequality system.

$$Cs > 0$$
$$s = (s_0, s_1, \ldots, s_n)$$

A specific solution of the above inequality system is one of its several feasible solutions. If one of the performances of neural networks, for example, the generalization capacity, is taken as an objective function and the above inequalities are regarded as constraint conditions, the learning problem can be transformed into some sort of programming (optimization) problems as follows.

Problem 1

Objective: $\max_s \min_i \{< s, c^i >\}$, where <x, y> is the inner product of x and y.

Constraint:

$$Cs > 0, \quad |s| = 1$$
$$C = \begin{bmatrix} c^1 \\ c^2 \\ \cdots \\ c^m \end{bmatrix}$$

Problem 1 is a quadratic programming problem and can equivalently be transformed into the following problem 2 and 3.

Problem 2

Let **C** be the convex closure of $\{c^i$, simply the convex closure of samples. Find s^* such that

$$|s^*| = \min_{s \in C} |s|$$

Problem 3

Find λ such that $\min_{\lambda \in R} \lambda^T Q \lambda$

Where $R = \left\{ \lambda \middle| \lambda_i \geq 0, \sum_{i=1}^{m} \lambda_i = 1 \right\}$ and Q is a positive semi-definite matrix.

Problem 2 is a geometric representation of problem 1. By using the geometric intuition of problem 2, some well-known methods such as simplex algorithms can be used to develop some efficient algorithms. We have presented a learning algorithm called iterative simplex algorithm with the polynomial complexity by using this idea.

Problem 3 is an algebraic form of problem 2. Some well-known programming techniques can be used to deal with the problem. For example, in [6] the potential reduction algorithm [7] was used to construct a programming based algorithm with the polynomial complexity.

Therefore, the computational complexity for finding the optimal separating hyperplane is reduced by these new algorithms.

3. KERNEL FUNCTION APPROACH

When the given sample set is linearly non-separable, the idea of the SVM is the following: It maps the input vector x into a high-dimensional feature space Z through some nonlinear mapping, chosen a priori. In this space, an optimal separating hyperplane is constructed. The advantage of the kernel function approach presented by Vapnik is that for constructing the optimal separating hyperplane in the feature space Z, one does not need to consider the high-dimensional feature space in explicit form. One only has to deal with a kind of kernel functions defined in the original space. The problem is how to find a proper kernel function such that in the new space the sample set is linearly separable and the separating hyperplane constructed generalizes well. To this end, we presented a new approach called covering algorithms [8][9].

In [8][9], the learning problem (classification problem) of neural networks was transferred into that of the point set covering in the input space of samples. Assume that $K = \{K_1, K_2\}$, $K = \{x^1, x^2, .., x^m$, is a set of input vectors of training samples, a point set in an n-dimensional space. Assume that K is classified into two classes K_1, K_2. From form (2), it's known that a neuron can be considered as a hyperplane below in the input space geometrically.

$$P: f\left(\sum_{j=1}^{n} w_j x_j - \theta\right) = 0 \qquad (3)$$

It divides the space into two half-spaces. When the input vector falls in the positive half-space, the corresponding output will be 1, otherwise –1. Based on the geometric interpretation, a constructive learning approach may be given. But when the number of hyperplanes (neurons) increases, the geometric intuition will lose, since each hyperplane extends infinitely. To this end, in our approach all points of K are projected upward to a hyper-sphere SP, where SP is a hyper-sphere with radius $r > \max_i |x^i|$ in $(n+1)$-dimensional space. Then the intersection between sphere SP and hyperplane P is a localized sphere neighborhood or a localized covering C_i. Each covering C_i represents a neuron. Due to the geometric intuition, based on the given sample set a neural network can easily be constructed as follows. That is, a set $C = \{C_1, ..., C_m\}$ of coverings is constructed such that each C_i only covers the points in one of $K_i, i = 1,2$ and the union of C_i covers the whole K. The C is called a classification cover set of K, since each $C_i \in C$ represents the

classification (K_1 or K_2) of the input vectors covered by C_i. A neural network performing the classification $K = \{K_1, K_2\}$ can be constructed by using the set C of coverings. Then, the learning problem (classification) in neural networks is transformed into the covering problem of input vectors. In the covering algorithm, the classification is performed by several separating hyperplanes in the *(n+1)*-dimensional sphere space rather than by only one separating hyperplane in the high dimensional feature space in SVM. But they are equivalent. The advantages of the covering algorithm are: (1) for any given sample set, the samples can always be separated without classification error by using several separating planes; (2) since the algorithm is performed in rather low dimensional (i.e., *n+1*) space, the separating planes that generalize well can easily be constructed by using the geometric intuition. However, since the dimensionality of the feature space is huge, in the SVM it's hard to choose a proper kernel function to guarantee lower classification error and higher generalization ability.

Let C be a classification cover set. If any C_i is deleted from C $C/\{C_i\}$ will no longer become a classification cover set, then C is called a classification cover set without redundant. Based on the approach presented in [7], the following theorem can be proved.

Theorem 1: Assume that $C = \{C_1, ..., C_m\}$ is a classification cover set of K without redundant, the first t coverings cover K_1 and the last *m-t* coverings cover K_2. Let $D_i = C_i \cap K_1, i = 1, ..., t$, $D_i = C_i \cap K_2, i = t+1, ..., m$. Set E_i is a non-empty subset of D_i and E_i do not intersect with each other. There must exist a kernel function with $E = \cup E_i$ as its support vectors.

The theorem indicates that any subset of input vectors of the given sample set may become the support vectors through some nonlinear mapping (or kernel function). Since the set of support vectors changes with different kernel functions arbitrarily, it means that support vectors do not always represent the essential classification property of the given sample set. Therefore, to construct a separating hyperplane that separates the training data and has maximal margin in the high dimensional feature space Z does not necessarily generalize well. It depends on what type of nonlinear mappings Z is used. Since the distance measure defined in the feature space is quite different from that defined in the original space, choosing a proper kernel function or a proper nonlinear mapping Z is very important in the SVM. To this end, we have proposed the new covering algorithms above. Its basic idea is the following.

Assume that a given sample set is divided into two classes. In the original input vector space (or *n+1*-dimensional sphere space) of the given sample set, finding the representative vectors (called separating points) of the boundary between two classes is easier than in the high dimensional feature space. Then, by using the separating points, a proper mapping Z can be constructed. The covering algorithms just benefit from processing in the lower dimensional space.

3. APPLICATIONS

3.1 Handwritten Chinese character recognition [10]

试读结束，需要全本PDF请购买 www.ertongbook.com