Adaptive quasiconformal kernel discriminant analysis

Jeng-Shyang Pan\textsuperscript{a,b}, Jun-Bao Li\textsuperscript{b,*}, Zhe-Ming Lu\textsuperscript{c}

\textsuperscript{a}Department of Electronic Engineering, National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan
\textsuperscript{b}Department of Automatic Test and Control, Harbin Institute of Technology, Harbin, China
\textsuperscript{c}Department of Electronics and Engineering, Sun Yat-Sen University, Guangzhou, China

Received 28 April 2006; received in revised form 30 September 2007; accepted 1 October 2007

Available online 23 October 2007

Abstract

Kernel discriminant analysis (KDA) is effective to extract nonlinear discriminative features of input samples using the kernel trick. However, the conventional KDA algorithm endures the kernel selection which has significant impact on the performances of KDA. In order to overcome this limitation, a novel nonlinear feature extraction method called adaptive quasiconformal kernel discriminant analysis (AQKDA) is proposed in this paper. AQKDA maps the data from the original input space to the high dimensional kernel space using a quasiconformal kernel. The adaptive parameters of the quasiconformal kernel are automatically calculated through optimizing an objective function designed for measuring the class separability of data in the feature space. Consequently, the nonlinear features extracted by AQKDA have the larger class separability compared with KDA. Experimental results on the two real-world datasets demonstrate the effectiveness of the proposed method.

Keywords: Kernel method; Quasiconformal kernel; Kernel discriminant analysis; Adaptive quasiconformal kernel discriminant analysis; Feature extraction

1. Introduction

Linear discriminant analysis (LDA) is a traditional dimensionality reduction technique for feature extraction. It has been widely used and proven successful in a lot of real-world applications. LDA works well in some cases, but it fails to capture a nonlinear relationship with a linear mapping. In order to overcome this weakness of LDA, the kernel trick is used to represent the complicated nonlinear relationships of input data to develop kernel discriminant analysis (KDA) algorithm. Kernel-based nonlinear feature extraction techniques have attracted much attention in the areas of pattern recognition and machine learning \cite{8,18,21,28}. Some algorithms using the kernel trick are developed in recent years, such as kernel principal component analysis (KPCA) \cite{21}, kernel discriminant analysis (KDA) \cite{17} and support vector machine (SVM) \cite{25}. KPCA was originally developed by Scholkopf et al. \cite{23}, while KDA was firstly proposed by Mika et al. \cite{17}. KDA has been applied in many real-world applications owing to its excellent performance on feature extraction. Researchers have developed a series of KDA algorithms (Lu \cite{14}, Baudat and Anouar \cite{2}, Liang and Shi \cite{10–12}, Yang \cite{32,33}, Lu \cite{15}, Zheng \cite{36}, Huang \cite{5}, Wang \cite{27} and Chen \cite{4}, Liang \cite{9}, Zheng \cite{35}, Tao \cite{26}, Xu \cite{31}, Saadi \cite{20}, Yeung \cite{34}, Shen \cite{24}, Ma \cite{16}, Wu \cite{29}, Liu \cite{13}). Because the geometrical structure of the data in the kernel mapping space, which is totally determined by the kernel function, has significant impact on the performance of these KDA methods. The separability of the data in the feature space could be even worse if an inappropriate kernel is used. In order to improve the performance of KDA, many methods of optimizing the kernel parameters of the kernel function are developed in recent years (Huang \cite{5}, Wang \cite{27} and Chen \cite{4}). However, choosing the parameters for kernel just from a set of discrete values of the parameters does not change the geometrical structures of the data in the kernel mapping space. In order to overcome the limitation of the
choosing but there are some essential questions should be.
The AQKDA algorithm works well on two real dataset,
optimizing an objective function designed for measuring
changes automatically the quasiconformal kernel structure
to the input data for classification because AQKDA

4. Conclusion and future work
In this paper, we develop a novel kernel-based learning
method called AQKDA algorithm for feature extraction. Com-}
pared with KDA, AQKDA is more adaptive to the input data for classification because AQKDA
changes automatically the quasiconformal kernel structure
with the adaptive parameters which are computed through
optimizing an objective function designed for measuring
the class separability of data in the feature space. The AQKDA algorithm works well on two real dataset, but there are some essential questions should be answered in the future: (1) Are there other methods of choosing \( \delta \) besides the cross-validation method? (2) If the number of samples and classes is very large then time consuming of solving the expansion coefficients becomes a challenge work owing to the large dimension of the matrix \( E \). How to increase the computation efficiency of optimizing the quasiconformal kernel when the size of dataset is very large?

<table>
<thead>
<tr>
<th>Performance comparisons of AQKDA, KDA, KPCA and KWMDA on ORL and YALE face databases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>AQKDA</td>
</tr>
<tr>
<td>KDA</td>
</tr>
<tr>
<td>KPCA</td>
</tr>
<tr>
<td>KWMDA</td>
</tr>
</tbody>
</table>

Acknowledgement
The authors would like to thank the anonymous reviewers for their constructive comments.

References


Jeng-Shyang Pan received the B.S. degree in Electronic Engineering from the National Taiwan University of Science and Technology, Taiwan in 1986, the M.S. degree in Communication Engineering from the National Chiao Tung University, Taiwan in 1988, and the Ph.D. degree in Electrical Engineering from the University of Edinburgh, U.K. in 1996. Currently, he is a Professor in the Department of Electronic Engineering, National Kaohsiung University of Applied Sciences, Taiwan. Professor Pan has published more than 50 journal papers and 120 conference papers. He joins the editorial board for LNCS Transactions on Data Hiding and Multimedia Security, Springer, International Journal of Knowledge-Based Intelligent Engineering Systems, IOS Press, and International Journal of Hybrid Intelligent System, Advanced Knowledge International. He is the Co-Editors-in-Chief for International Journal of Innovative Computing, Information and Control. His current research interests include data mining, information security and image processing.

Jun-Bao Li received the B.Sc. and M.Sc. degree from Harbin Institute of Technology (HIT), Harbin, P.R. China in 2002 and 2004, respectively. He is currently working toward the Ph.D. degree in the Measurement Technology and Instrument, in HIT, Harbin, P.R. China. His research interests are mainly in pattern recognition and image processing.

Zhe-Ming Lu was born in Zhejiang Province, China, in 1974. He received the B.S. and M.S. degrees in electrical engineering and the Ph.D. degree in measurement technology and instrumentation from the Harbin Institute of Technology (HIT), Harbin, China, in 1995, 1997, and 2001, respectively. He became a Lecturer with HIT in 1999. Since 2003, he has been a Professor with the Department of Automatic Test and Control, HIT. Now, he is the Professor of Department of Electronics and Engineering, Sun Yat-Sen University, Guangzhou, China. He has published more than 120 papers and two books (in Chinese) Vector Quantization Fundamentals and Applications (Beijing, China: The Science Press, 2002) and Digital Watermarking Techniques and Applications (Beijing, China: The Science Press, 2004). He also participated in a chapter entitled Watermarking Based on Vector Quantization in the book Intelligent Watermarking Techniques by J.S. Pan, H.-C. Huang, and L.C. Jain (editors) (Singapore: World Scientific, 2004). His current research interests include speech coding, image processing, and information security. Dr. Lu has been a Senior Member of IEEE since 2006 and the Member of SPIE and the Chairman of Youth Science and Technology Association of HIT since 2003. He organized and chaired the invited session titled Image Compression and Digital Watermarking Techniques in the 7th World Multiconference on Systemics, Cybernetics, and Informatics (SCI 2003), July 27’C30, 2003, Orlando, FL. He is the program committee member in more than six international conferences (IIHMS2005, CIS2005, ICICIC2006, ICPR2006, IWDW2006, CIS2006). He is the Associate Editor of International Journal of Innovation Computing and Information Control and the Executive Editor of International Journal of Computer Sciences and Engineering Systems. He was the Alexander von Humboldt Research Fellow in University of Freiburg, Germany during Oct. 2004 to Jan. 2006. He was awarded one of the 2003 One Hundred Most Excellent Doctors in China award for authoring more than 40 papers in the field of vector quantization. One of his papers was also rewarded as one of ten best papers in KES 2005.