論文 / 著書情報
Article / Book Information

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Title(English)	Feature Extraction and Classification Methods for Multi-way Data Analysis
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The world is filled with data which have various types such as numeric data, non-numeric data, continuous valued data, discrete valued data, scalar data, vector data, matrix data, and higher-dimensional array data. Continuous valued and multi-dimensional array data is denoted by the ``multi-way data'' which can be processed by the computers. Thus, the multi-way data includes a scalar, a matrix, and a higher-dimensional array of continuous values. Techniques of multi-way data analysis play important roles in wide research fields such as audio processing, image processing, bioinformatics, chemometrics, and brain science.

In this thesis, after the techniques of feature extraction and classification methods for multi-way data analysis are summarized; new criteria and solving algorithms are proposed for them, and their advantages are demonstrated by experiments. Matrix/tensor decomposition has been widely used for visualization, clustering, blind source separation, and dimensionality reduction of multi-way data. We often impose some constraints such as orthogonality, sparsity, and nonnegativity based on the characteristics of target data. Techniques for the constraints such as singular value decomposition (SVD), penalized matrix decomposition (PMD), and nonnegative matrix factorization (NMF) have been well studied.

Function approximation in NMF is a technique to represent nonnegative feature vectors by linear combinations of basis functions. For example, if we choose smooth basis functions, then smooth feature vectors can be obtained. Zdunek proposed this technique as the GRBF-NMF method which uses the Gaussian radial basis functions for function approximation. However, its algorithm, in which the QP optimization and the active-set algorithm run alternately and iteratively, is so slow that it can not be applied to large-scale problems. Then, I propose a new fast algorithm for the function approximation by NMF, and choose more effective basis functions for function approximation. Furthermore, I extend this method to the nonnegative Tucker decomposition and the nonnegative canonical polyadic (CP) decomposition.

The common and individual feature extraction is a very important concept for data analysis because real world data always have some common and individual features.
For examples all human faces have two eyes, two ears, a nose, and a mouse (common feature);

but, their positions and shapes are different as individual personalities (individual feature). However, existing techniques for it are not efficient very well, and their techniques have been developed only for matrices. Then, I propose a tensor based common and individual feature extraction method in CP and Tucker model, and impose orthogonality, sparsity, and nonnegativity constraints to both models.

Classification techniques are used for various objectives such as brain computer interface (BCI), fingerprinting identification, hand-written character recognition, and face recognition. In recent years, the support vector machine (SVM) has been the most popular classifier; however, SVM does not always provide the best performance. The criterion of SVM consists of the hinge-loss minimization and a regularization. In this research, I propose two novel weighted regularization methods for a variety of applications. Furthermore, I apply these regularization methods to the conventional SVM.

The Fisher discriminant analysis (FDA) is another famous method for classification. However, FDA does give an optimal projection only for Gaussian distributions with equal covariance matrices. In other words, FDA is not optimal in the case of heteroscedastic Gaussian distributions. In this research, I propose a novel criterion for FDA including a correction term based on the Bhattacharyya distance which is closely related to classification rate. Furthermore, the Chernoff distance based criterion and its kernelized version are proposed as its extensions.

The final proposition of this thesis is a new criterion of classifier based on the maximum a posteriori (MAP) estimation for a binary problem without estimating the posterior probability, called the quadratically constrained maximum a posteriori (QCMAP) estimation. The QCMAP consists of the maximization of the expectation of a cost function, which is derived from the maximum a posteriori probability, and a quadratic constraint. This criterion is highly general since its forms include least squares regressions (LSRs) and a SVM. I propose several efficient classifiers from the criterion by selecting various weight functions.

Finally, I show the experimental results of all proposed methods to demonstrate their advantages for the feature extraction and the pattern classification. In the experiments, the proposed smooth NMF/NTF algorithms using function approximation are applied to reconstruction of two and three dimensional array data, blind source separation, part-based representation to compare with other NMF methods (unconstrained, sparse and smooth NMF algorithms); the proposed common and individual feature extraction algorithms based on Tucker and CP decomposition models are applied to reconstruction and multi-way blind source separation; the proposed regularized SVM, Chernoff based FDA, and QCMAP classifiers are applied to several toy well-known benchmarks and real-world brain computer interface (BCI) problems to compare with other classification methods.