Chapter XVII
Independent Component Analysis and its Applications to Manufacturing Problems

Xian-Chuan Yu
Bejing Normal University, China

Hui He
Bejing Normal University, China

Ting Zhang
Bejing Normal University, China

Wei Zou
Bejing Normal University, China

Li-Bao Zhang
Bejing Normal University, China

Meng Yang
Bejing Normal University, China

ABSTRACT

Independent component analysis (ICA) is a statistical method for transforming an observed multidimensional random vector into components that are as independent as possible. In this chapter, we introduce the background information, the theory of ICA, and present several common algorithms such as fast ICA, kernel ICA, and constrained ICA. It is first applied to mineral resources prediction and remote sensing imagery, while traditional methods cannot satisfy the complexity of the spatial data (prospecting geochemistry data, remote sensing data, etc.). In application cases, ICA is applied to analyze the spatial data in some districts of China. The result shows that some independent elements accord with the practical distribution better than conventional methods. Moreover, ICA can get rid of the various kinds of correlations in remote sensing imagery effectively and improve the classification accuracy. However, this method also has some limitations. At last, we list the future research directions of our work.

INTRODUCTION

Independent component analysis (ICA), which is developed from blind source separation (BSS), is the identification and separation of mixtures of sources with little prior information. It is also used in the feature extraction.

In the beginning, the basic ICA data model is linear and without noise. The model is often estimated by choosing an appropriate objective function then maximizing or minimizing it by the optimization algorithm. The objective function decides the statistic characters such as asymptotic variance, robustness, and so on. The optimization algorithm decides the algorithm's characteristics, such as the convergence speed, the numeric stability, and so forth. In the actual research, objective functions, those most extensively used, are likelihood and network entropy, negentropy, mutual information, Kullback-Leibler divergence, and high order cumulation.

In data mining and pattern recognition, independent component analysis is very useful and gradually becomes a hot problem in signal processing. Now ICA is widely applied in biomedicine signal processing, sound signal separation, communication, error diagnose, feature extraction, financial time sequence analysis, data mining, astronomy, and so forth. For example, ICA could provide solutions to denoise electroencephalogram (EEG), magneto encephalography (MEG), or functional magnetic resonance imaging (FMRI) signals for medical applications (Makeig, Bell, Jung, & Sejnowski, 1996; Mckeown, Jung, Makeig, et al., 1998; Vigário, Jousmaki, Hamalainen, Hari, & Oja, 1998), it could separate mixed sound signals (Li & Sejnowski, 1994), and reveal the factors to reduce the investment risk from the economic time sequence data (Mlroiu, Kiviluoto, & Oja, 2000). ICA could also be applications for code division multiple access (CDMA) communications (Ristaniemi, Raju, & Karhunen, 2002). At the same time, it has been used to extract features from natural images (Olshausen & Field, 1996; van Hateren & van der Schaaf, 1998). Recently, ICA has been explored for the feature extraction from multicolored and solid 3D images (Hoyer & Hyvrinen, 2000). The mixture model has been developed to extend to solving general unsupervised classification and data mining problems beside the simple ICA, which has been used as a tool for unsupervised analysis of hyper spectral images.

In manufacturing fields, ICA is also very important. For example, in voice control computer, ICA can help recognize the correct speech commands in noise environment and other signals if the locations of the sources and the receive devices are unknown.

In this chapter, we will introduce the main theory and algorithms of ICA, then present its two novel applications. One is mineral resources prediction of geology and the other is remote sensing imagery information extraction of geography.

BACKGROUND

For blind source separation, several methods have been proposed, such as principle component analysis (PCA), factor analysis (FA), projection pursuit, redundancy reduction, and blind deconvolution. PCA and FA belong to the second order separation method; however, the actual signification is usually explicit. PCA assumes the original data satisfying with the Gauss distribution emphasis to reduce the dimensions, so the compute precision is not very high. And the eigenvectors after PCA are orthonormal which do not accord with a great deal of natural information in the real world. The high order separation methods conclude projection pursuit, redundancy reduction and blind deconvolution. Whereas they also request that the data obey Gauss distribution.

ICA inherits the advantages of the theories above and modifies some disadvantages. For example, ICA assumes that the original data are non-Gauss distribution, which is also a re-

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