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研究課題名（和文）Common and Individual Feature Analysis and Its Applications in BCI

研究課題名（英文）Common and Individual Feature Analysis and Its Applications in BCI

研究代表者
周　郭許（ZHOU, GUOXU）

国立研究開発法人理化学研究所・脳科学総合研究センター・研究員

研究者番号：８０６０８０３４

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研究成果の概要（和文）：本研究課題の実績は以下の4つにまとめることができる。
①互いに関係をもつ複数データから共通特徴および個別特徴を同時に抽出するための新しい枠組み(CIFA)を提案した。②高次元の複数データから支配的な共通成分を取り出すための有効な特徴抽出アルゴリズムを開発した。③複数の被験者の脳波を用いた定常状態視覚誘発電位(SSVEP)に基づく脳コンピュータインターフェース(BCI)システムを構築した。④提案した特徴抽出法(CIFA)を導入することによって、BCIシステムにおけるSSVEPの識別精度を大きく向上させることに成功した。
また、本研究成果は8件の学術論文および2件の国際会議にて発表された。

研究成果の概要（英文）：(1) We proposed a new framework for the common and individual features analysis (CIFA) of multi-block linked data. (2) We developed several efficient algorithms for tensor decompositions, which can be used to extract common features from multi-block high-dimensional data where these common features are dominant. (3) We built a steady-state visual evoked potential (SSVEP) based BCI system and recorded EEG signals of multiple subjects and trials which were under same stimuli. These data were analyzed by CIFA, and we achieved so-far the highest accuracy in target frequency recognition.

研究分野：情報学

キーワード：データ統合　共通・個別特徴解析　結合成分解析　テンソル分解

１．研究開始当初の背景

The emergence of high-dimensional data structures requires new data analysis tools to be able to deal with the many aspects of this multifaceted problem, from data representation and interpretation to information retrieval. In this context, multi-block data analysis techniques are particularly interesting, as they accommodate multiple measurements of the same phenomenon under various experimentation conditions. For example, human electrophysiological signals in response to a certain stimulus, but from different subjects and trials, can be grouped together and naturally linked as multi-block data. Such data blocks share common information, and at the same time they also allow for individual data features to be kept. Intuitively, this common shared information should help to discover connections between members of a data ensemble and can be used to characterize this data ensemble, while the individual features may help to recognize or identify each individual member of the data ensemble. The identification and separation of such common and individual information in order to employ the features highly relevant to the data analysis task at hand promises to significantly improve data analysis. For example, shared features among tasks have been exploited to improve the performance of supervised and semi-supervised learning. In this project, we focus on an unsupervised learning framework for the extraction of common and individual features across multi-block data and its applications in brain-computer interface (BCI).

２．研究の目的

Our aims are to develop new models and algorithms for group analysis of naturally linked multi-block and high-dimensional data to discover their common and individual features, and to apply them to EEG-based affective brain computer interfaces to find real reliable common response to certain stimuli across different subjects, which will help us not only to better understand functions of the human brain but also to develop more practical (more accurate and efficient) BCI systems.

３．研究の方法

First, we performed theoretical analysis on the data and proposed our new model and algorithms using mathematics (statistics, algebra, optimization). Then, we used synthetic data to verify whether the developed models and algorithms were able to yield desired results. On the basis of simulation results, we revised and improved our model and algorithms.
Finally, we applied our new methods to real-world data, particularly, steady-state visual evoked potential (SSVEP) data. For SSVEP data, the common components are expected to identify the target frequencies. Hence, the proposed method is very suitable for analyzing such multi-block data and it turned out that the performance was very promising.

４．研究成果

① We proposed two algorithms for common orthogonal basis extraction (COBE) in order to extract common orthogonal basis from multi-block data, upon which a new framework for the common and individual features analysis (CIFA) of multi-block linked matrix/tensor data was developed. We released the corresponding MATLAB code for academic use.
② We developed several efficient algorithms for constrained tensor decompositions (including nonnegative canonical polyadic decomposition and nonnegative Tucker decomposition), which can be used to extract common features from multi-block high-order tensor data provided that these common features are dominant.
③ We proposed new methods for linked blind source separation, clustering, and classification by exploiting the extracted common and/or individual features. Our experimental results showed that CIFA was able to extract highly task-relevant features and hence significantly improve the accuracy of data analysis.
④ We built a steady-state visual evoked potential (SSVEP) based BCI system and recorded EEG signals of multiple subjects and trials which were under same stimuli. These data naturally share some common features reflecting the same stimuli but also have their own individual features associated with a specific subject and trial. These data are available online and free for academic purposes.
⑤ We applied the proposed CIFA to SSVEP-based BCI and achieved so-far the highest accuracy in target frequency recognition.

We published 10 journal papers and 2 conference papers with my colleagues, released 1 MATLAB toolbox (TDALAB) for tensor decomposition and analysis.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計　10　件）

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〔学会発表〕（計　2　件）

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[2] G. Zhou, Q. Zhao, Y. Zhang, and A. Cichocki, Fast nonnegative tensor factorization by using accelerated proximal gradient, Advances in Neural Networks (ISNN 2014,国際学会), 2014.11.28-12.1, Hong Kong and Macao.

〔図書〕（計　0　件）

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〔その他〕
ホームページ等

６．研究組織

(1)研究代表者

周　郭許（Guoxu Zhou）

国立研究開発法人理化学研究所・脳科学総合研究センター・研究員

研究者番号：８０６０８０３４

(2)研究分担者

（　無　）

研究者番号：

(3)連携研究者

（　無　　）

研究者番号：