BMI 500: Introduction to Biomedical Informatics
Fall 2021

Exercises of Lecture 11. An Introduction to Blind Source Separation and Independent Component Analysis

Instructor: Reza Sameni
Email: rsameni@dbmi.emory.edu

INSTRUCTIONS:

For the following exercises, please proceed as follows:

1) Clone and fork the BSS lecture Git repository (address noted in the References)
2) Update the repository as required in each question
3) Send a pull request for the original Git project with your updates by **8th November 2021, 5pm EST.**

Note 1: The reports should be added to the README.md file and structured as follows (below the current contents of the original README file):

```
### Student Name: [Your name]
### Student Email: [Your email]
***
### Question 1
#### Part A
[Your report]
#### Part B
[Your report]
#### Part C
[Your report]
...
***
### Question 2
#### Part A
[Your report]
...
```

Note 2: You can save and include MATLAB images or photos of your hand-written notes or derivations in the Markdown reports.

Office Time: I am available throughout the week for any questions about the exercises by email.

QUESTIONS:

Question 1:

A) Calculate the eigenvalues and eigenvectors of the matrix $C = \begin{pmatrix} 5 & 1 \\ 1 & 2 \end{pmatrix}$ by mathematical derivation (handwritten with details, no need to type, just take a photo and include it in your Markdown report).
B) Check and compare your results with the "eig" function in MATLAB and report the values in your report.

Question 2:

A) Recalculate the eigenvalues of Question 1 by using the Power Method.
B) Plot the two entries of the principal vector and the leading eigenvalue in the first twenty iterations of the Power Method.

Question 3:

A) Revise (by change of parameters or input signals and adding comments) and rerun the MATLAB sample m-files Ex01 to Ex05 from the BSS lecture repository, on arbitrary biological signals from the open-source electrophysiological toolbox (OSET), or the PhysioNet database.
B) Update the GitHub Markdown file (README.md) with a short and structured report on your personal interpretation of the functionality of the code and the results that you obtain from part A (about 150 words per each m-file). For Ex05, only select and run one of the commented OSET scripts and report your findings regarding the functionality of the script.

Question 4:

A) Choose one of the following papers and write a summary of the paper in 250 words or more including the pseudo-code of the BSS algorithm of the paper.
B) *(Optional-Bonus)* Implement the BSS algorithm of the selected paper in MATLAB or Python and apply it on a real signal/image.

Title	Topic
Cao, L. J., Chua, K. S., Chong, W. K., Lee, H. P., & Gu, Q. M. (2003). A comparison of PCA, KPCA and ICA for dimensionality reduction in support vector machine. *Neurocomputing*, *55*(1-2), 321-336. DOI: https://doi.org/10.1016/S0925-2312(03)00433-8	Relationship between ICA and machine learning algorithms
Cardoso, J-F., and Beate H. Laheld. "Equivariant adaptive source separation." *IEEE Transactions on signal processing* 44.12 (1996): 3017-3030. DOI: https://doi.org/10.1109/78.553476	ICA for continuous stream of signals (online ICA)
Sameni, Reza, Christian Jutten, and Mohammad B. Shamsollahi. "Multichannel electrocardiogram decomposition using periodic component analysis." *IEEE transactions on biomedical engineering* 55.8 (2008): 1935-1940. DOI: https://doi.org/10.1109/TBME.2008.919714	ICA for pseudo-periodic signals such as the ECG

Sameni, Reza, Christian Jutten, and Mohammad B. Shamsollahi. "A deflation procedure for subspace decomposition." *IEEE Transactions on Signal Processing* 58.4 (2009): 2363-2374. DOI: https://doi.org/10.1109/TSP.2009.2037353	BSS for degenerate mixtures of signals with biomedical applications
Jutten, Christian, and Jeanny Herault. "Blind separation of sources, part I: An adaptive algorithm based on neuromimetic architecture." Signal processing 24.1 (1991): 1-10. DOI: https://doi.org/10.1016/0165-1684(91)90079-X	A basic ICA algorithm, which can be used as a node in neural networks including DNN
Zou, Hui, Trevor Hastie, and Robert Tibshirani. "Sparse principal component analysis." *Journal of computational and graphical statistics* 15.2 (2006): 265-286. DOI: https://doi.org/10.1198/106186006X113430	PCA with sparsity constraint
Mohimani, Hosein, Massoud Babaie-Zadeh, and Christian Jutten. "A fast approach for overcomplete sparse decomposition based on smoothed L0 norm." *IEEE Transactions on Signal Processing* 57.1 (2008): 289-301. DOI: https://doi.org/10.1109/TSP.2008.2007606	Sparse component analysis
Davies, Mike E., and Christopher J. James. "Source separation using single channel ICA." *Signal Processing* 87.8 (2007): 1819-1832. DOI: https://doi.org/10.1016/j.sigpro.2007.01.011	Audio source separation using ICA
Lee, Te-Won, Michael S. Lewicki, and Terrence J. Sejnowski. "ICA mixture models for unsupervised classification of non-Gaussian classes and automatic context switching in blind signal separation." IEEE Transactions on Pattern Analysis and Machine Intelligence 22.10 (2000): 1078-1089. DOI: https://doi.org/10.1109/34.879789	ICA for unsupervised classification
Jung, Tzyy-Ping, et al. "Extended ICA removes artifacts from electroencephalographic recordings." *Advances in neural information processing systems*. 1998. https://dl.acm.org/doi/10.5555/302528.302849	ICA for EEG noise removal
Lu, Wei, and Jagath C. Rajapakse. "Approach and applications of constrained ICA." *IEEE transactions on neural networks* 16.1 (2005): 203-212. DOI: https://doi.org/10.1109/TNN.2004.836795	Constrained ICA with image processing applications
Jung, T. P., Makeig, S., Humphries, C., Lee, T. W., Mckeown, M. J., Iragui, V., & Sejnowski, T. J. (2000). Removing electroencephalographic artifacts by blind source separation. *Psychophysiology*, *37*(2), 163-178. DOI: https://doi.org/10.1111/1469-8986.3720163	ICA for EEG noise removal
Subasi, Abdulhamit, and M. Ismail Gursoy. "EEG signal classification using PCA, ICA, LDA and support vector machines." *Expert systems with applications* 37.12 (2010): 8659-8666. DOI: https://doi.org/10.1016/j.eswa.2010.06.065	Relationship between ICA and machine learning algorithms

REFERENCES:

- The BSS lecture Git repository: https://github.com/rsameni/BSSLecture.git
- OSET: https://gitlab.com/rsameni/OSET.git
- The PhysioNet Databases: https://physionet.org/about/database/