CS 280
Programming Assignment 3
Cocktail Party Problem

Helbert Paat

University of the Philippines
hapaat@up.edu.ph

December 31, 2020

I. Independent Component Analysis

Independent Component Analysis is an unsupervised learning algorithm used to find the independent signal sources given some data $x \in \mathbb{R}^d$ that are mixtures of the sources. The observed data x is

$$x = As$$

where A is called the mixing matrix. A is an unknown square matrix that performs the mixing mechanism. The dataset $\{x(i); i = 1, ..., n\}$ consist of repeated observations. The goal of ICA is to recover the sources $s(i)$ that generated the observed data. In order to do this, define W to be $W = A^{-1}$. W is called the unmixing matrix. More specifically, the goal of ICA is to find W. By computing $s = Wx$, the sources can be recovered.

In this paper, consider a classic application of ICA, the "cocktail party problem." In a party, sounds are produced simultaneously by d different speakers. Consider the situation where d microphones are also placed in different places in the room. Then, the overlapping combination of the sounds from the d speakers are recorded by any of the d microphones. These microphones record different combination of the sounds from the speakers. The goal of ICA is to use these microphone recordings to produce the original d speakers' speech signals.

II. Methods

Five audio sources were used in this experiment. Using sklearn, FastICA is used to unravel the independent components from the audio sources.

a. The audio files mic1.wav to mic5.wav found in the given folder "Audio Data" were loaded using the $wavfile.read$ function from the Python library $SciPy$. Synchronized audio recordings recorded by five microphones at five different locations are contained in these files.

b. To form the mixture matrix X, the input files were concatenated using $numpy.c\_$. Using the same function, the input sampling rate was determined to be 22050.

c. In ICA, there are two main pre-procesing strategies: centering and whitening (also called sphering). Preprocessing before using ICA has the following advantages:

   - Algorithms are simplified
   - Dimensionality reduction
   - Features of the dataset that are not explained by mean and covariance are explained.
   - Number of parameters is reduced.

   In order to eliminate the mean-covariance information and to highlight important features such as outliers, clusters, and concentrations near curves or non-flat surfaces, centering and sphering are used [1]. These are often performed before data exploration and analysis as part of the pre-processing step.

   Centering: To center X, the mean of X was subtracted from all the elements of X.

d. Using the $fit\_transform(X)$ method from FastICA, the five independent components from the mixture of audio signals were determined.

e. **Whitening**: By default, the data is automatically whitened using FastICA from sklearn. However,

there is an option to not whiten the data by setting the value of the parameter "whiten" to False.

f. Experiment was conducted on the appropriate input sampling rate to be used.

g. Using the parameter "fun" in sklearn FastICA, experiment was conducted using different contrastive function $G(y)$. The contrastive function is used in the approximation to neg-entropy. In sklearn FastICA, the parameter "fun" can either be 'logcosh', 'exp', or 'cube'. Other functions can be manually provided as well.

h. After using FastICA, the independent components $\widehat{s}_i(t), i = 1, ..., 5$ were saved as audio files in wav format using the $wavfile$ module and were labeled as shat1.wav,...,shat5.wav.

i. Using the the sources matrix s calculated through FastICA. The mixture signals $\widehat{x}_i(t), i = 1, ..., 5$ were reconstructed using the $inverse\_transform(X)$ method from FastICA.

j. The Mean Squared Residual of the original mixture matrix X and $\widehat{X}$ were calculated and printed out.

k. By using the *write* function from the $wavfile$ module, the reconstructed mixture signals were saved as as audio files in wav format using the same 22050 sample rate and were labeled as recon1.wav,...,recon5.wav.

III. Results

In this paper, we experiment on three different contrastive functions by changing the value of the parameter "fun" in sklearn FastICA. Table 1 shows comparison of residuals when whitening and centering are used or not used and given different contrastive functions.

For the three contrastive functions used,a higher Mean Squared Residual is achieved when the data is whitened. Moreover, the Mean Squared Residual does not seem to vary significantly whether the data is centered or not. Among the three contrastive functions, "exp" seems to exhibit the least Mean Squared Residual. It can be concluded that using contrastive function with "exp" as value for the fun parameter when the data is whitened and centered (or not centered) yields the least Mean Squared Residual.

Figure 1 shows the plots of the original mixture signals of the five independent components, independent sources signals determined using FastICA, and the mixture signals reconstructed using FastICA.

G(y)	Centering	Whitening	Mean Squared Residual
logcosh	Yes	Yes	$1.17x10^{-23}$
logcosh	Yes	No	$7.36x10^{-23}$
logcosh	No	Yes	$1.33x10^{-23}$
logcosh	No	No	$1.59x10^{-23}$
exp	Yes	Yes	$4.74x10^{-24}$
exp	Yes	No	$4.55x10^{-23}$
exp	No	Yes	$4.54x10^{-24}$
exp	No	No	$3.75x10^{-23}$
cube	Yes	Yes	$8.08x10^{-24}$
cube	Yes	No	$8.83x10^{-22}$
cube	No	Yes	$4.43x10^{-24}$
cube	No	No	$2.66x10^{-22}$

Table 1: *Reconstruction residual for different configurations of the contrastive function and preprocessing steps*

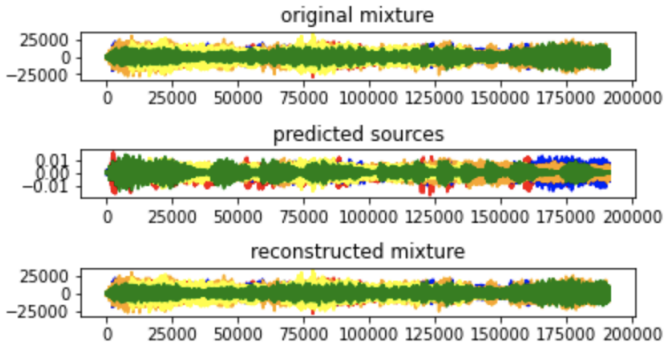

Figure 1: *Comparison of the plots of the original mixture signals, independent sources signals, and the reconstructed mixture signals using FastICA*

IV. Conclusions and Recommendation

In this paper, it has been shown how the independent sources of the mixture signals were generated using FastICA. Moreover, the original mixture signals were reconstructed using FastICA with minimal error. It has been shown that preprocessing steps like whitening and centering are necessary for ICA to perform better.

For future studies, one can experiment on different contrastive functions.

References

[1] G. Li and J. Zhang. *Sphering and its properties*. The Indian Journal of Statistics, Vol. 60, Series A, Part I, pp. 119-133, 1998.