Alternating Least Squares (ALS) blind source separation performance varied on dimension, salinity, and temperature water environment

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Abstract. This experiment conduct in mini semi-anechoic water test tank and towing tank at IHL. The purpose is to analyse performance from ALS algorithm in dimension, salinity and temperature water environment. For this purpose we varied water salinity and temperature in mini semi-anechoic water test tank, and for different dimension we took the experiment on two different size of test tank. The results showed that ALS have consistent result at salinity and temperature variety but at large dimension test tank 200 × 10 × 5.5 m without variation on the water medium indicates an anomaly in the results of the ALS BSS technique performance.

1. Introduction

Effort to get information from underwater where human have limited in using their eyes makes them using ears. Leonardo Da Vinci do some experiment to hear the sound come from underwater using a tube which one side he put on his outer ear and another in underwater, so he can hear sound of ship from the distance [1]. In modern day, extracting information from underwater sound have many challenges, both from technic and source. Crowded activities on the surface and underwater produce many sound and extracting information to distinguish which is useful information and not by computer have many ways from researcher.

One of the alternative way is called blind sources separation (BSS). Blind sources separation (BSS) is a technique used for source classification by simply observing the mixed signal (observation) with the medium or mixing system (matrix mixing). When researcher want to know what sounds are recorded by the microphone with simply exploring the observation signal, then the math will do the operation of the decomposition of sound (demixing). The matrix notation of the sound mixing process and its decomposition will appear as below [2].

\[ X(t) = AS(t) \] (1)

with \( X(t) = (x_1(t), ..., x_J(t)) \) is observation signal, \( A \) is mixing matrix and \( S(t) \) is source signal. Then to get source signal expectation, the equation can be assumed by reversing the mathematical model from (1) to,
\[ \hat{S}(t) = X(t)A^{-1} \]  

with \( \hat{S}(t) \) represent source signal expectation, \( A^{-1} \) is demixing matrix and \( X(t) \) is observation signal.

2. Problem Address

2.1. Alternating Least Squares (ALS).
In order to apply equation (1) and (2) there are two problems: first the system matrix (mixing matrix) must be known, and the second place where mixing noise occur must noise free or ideal. This condition is impossible to achieve in real world case because ideal noise less environment without interruptions are none. Then adjustment for the equation above need to be made.

\[ X(t) = \sum_{k=-\infty}^{\infty} A S(t - k) \]  

Equation (3) occur because in un-ideal environment mixing sound process followed by echo effect. Delay echo effect in mathematic have same meaning with equation (4).

\[ X(t) = \sum_{k=-\infty}^{\infty} A * S(t) \]  

So equation (4) called convolutive mixture. Another problem from real world case is the only one information we have are observation signal \( X(t) \) without information about mixing matrix \( \hat{A} \) and source signal \( S(t) \). Then we choose mathematic solution called Alternating Least Squares (ALS).

[3] have scheme for demixing matrix like Figure 1.

Terms apply for this method are:

- Number of sensors ≥ number of sources ≥ 2.
- Source \( s(t) \) have zero-mean, non-stationary. Cross spectral density of source \( P_s(\omega, m) \) is diagonal for all \( \omega \) and \( m \) with \( \omega \) is frequency bin and \( m \) is epoch. Note: epoch is time duration when signal assumed to be stationer.
- \( H(\omega) \) is Discrete Fourier Transform from \( H(z) \) is full column rank matrix. Full-rank is matrix with all linearly independent vector inside.

**Figure 1.** Flowchart getting a \( W \) matrix.
with $H(z)$ is $z$-transform matrix from $J \times N$ transfer function mixing matrix. $J$ get from how many matrix observation signals while $N$ get from how many matrix source signals. Then $\Pi$ is permutation matrix and $D$ is diagonal matrix. For $W \approx A^{-1} \approx H^{-1}$ [4].

2.2. Adjustment for water environment.
Retrieving data by bringing equipment that consist of transmitter and receiver to real sea then perform scanning process have disadvantages such as cost, transportation, time and energy big consume. This situation then encourages researchers to conduct laboratory experiments to reduce the inefficiencies caused by classic way data retrieval.

In line with laboratory-scale data retrieval solution, the pre-research conducted on this research has developed a semi anechoic mini test tank has dimension $2 \times 1 \times 1$ m with thickness 12 mm shows in Figure 2, as representation of water environment but with physical variables like temperature and salinity adapted to Indonesia water characteristics [5]. For dimension variation, we conduct another data retrieval at towing tank Indonesia Hydrodynamics Laboratory (BPPT, IHL) with dimension $200 \times 10 \times 5.5$ m.

3. Experiment Method [5]
First scenario we vary water environment at semi anechoic mini test tank with temperature 13°C, 17°C, 21°C, 25°C and 29°C. Same with first scenario, for the second we change the water environment with room temperature but vary in salinity are: 3.1%, 3.2%, 3.3%, 3.4% and 3.5%. Data retrieval using sources generated from 2 underwater speakers and 3 hydrophones. The sound sources consist single tone and multi tone. The third scenario, we conduct data retrieval at towing tank Indonesia Hydrodynamics Laboratory (BPPT, IHL).

![Figure 2. Semi anechoic mini test tank has dimension $2 \times 1 \times 1$ m with thickness 12 mm. There is sponge inside the test tank with high of bulge 2 cm for reduce the echo.](image1)

![Figure 3. Towing tank Indonesia Hydrodynamics Laboratory (BPPT, IHL) with dimension $200 \times 10 \times 5.5$ m.](image2)
4. Results

Based on mean squared error (MSE) measurement [4] from Figure 5 and Figure 6 shown that separation results (source expectation) at signal with kurtosis smaller give better approximation than another. This condition is consistent for all variation experiment, include salinity, temperature and dimension variation. Kurtosis is measure for how “peaky” probability density function (PDF) of an observation signal $X(t)$. More “peaky” the signal shown by greater score for their kurtosis, better separation achieved on all variation in this research. Kurtosis score for observation signal we used shown at Figure 7 and Figure 8.

5. Conclusion

Water environment variety we conduct in this research seems like have not significant effect to the results of BSS process algorithm using ALS. It shown that statistic properties have more roles than water environment variety.
Figure 5. MSE separation results comparison on experiment conduct at semi anechoic mini test tank

Figure 6. MSE separation results comparison on experiment conduct at towing tank

Figure 7. Joint distribution PDF from observation signal at semi anechoic mini test tank.
6. References
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