Audio Source Separation Report

Group 16

1 Algorithm Analysis

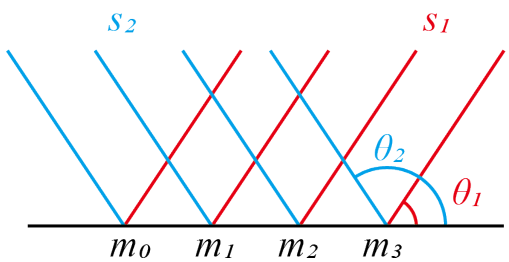
1.1 AoA Estimation

The AoA Estimation is based on the Delay-and-Sum Algorithm which has been described in the lab document and will not be repeated here.

1.2 Source Separation

Our Source Separation is also based on the Delay-and-Sum Algorithm, and the basic analysis is as follows.

There are 4 microphones $m_0 - m_3$, 2 audio sources signals $s_1(t), s_2(t)$, and 4 signals $x_0(t) - x_3(t)$, will be received, as shown below.



First we take the Fourier Transforms of the sources signals and the received signals.

$$s(t) \overset{FFT}{\Longrightarrow} S(f) \qquad x(t) \overset{FFT}{\Longrightarrow} X(f)$$

If the AoA between of source 1 and source 2 are θ_1, θ_2, then the delay is $\phi_1 = \frac{2\pi d cos(\theta_1) f_i k}{c}$, $\phi_2 = \frac{2\pi d cos(\theta_2) f_i k}{c}$, $k = 0, 1, 2, 3$

So the received signals can be written as

$$\begin{bmatrix} X_0 \\ X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} e^0 & e^0 \\ e^{j\phi_1} & e^{j\phi_2} \\ e^{j2\phi_1} & e^{j2\phi_2} \\ e^{j3\phi_1} & e^{j3\phi_2} \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix}$$

The purpose of the part 4 is to solve S_1 and S_2. According to the previous part, we already get θ_1 and θ_2 by AoA estimation, and then we preceed as follows.

$$\begin{bmatrix} e^0 & e^{-j\phi_1} & e^{-j\phi_2} & e^{-j\phi_3} \end{bmatrix} \begin{bmatrix} X_0 \\ X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} e^0 & e^{-j\phi_1} & e^{-j\phi_2} & e^{-j\phi_3} \end{bmatrix} \begin{bmatrix} e^0 & e^0 \\ e^{j\phi_1} & e^{j\phi_2} \\ e^{j2\phi_1} & e^{j2\phi_2} \\ e^{j3\phi_1} & e^{j3\phi_2} \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix}$$

$$= 4S_1 + \sum_{k=1}^{3} e^{jk(\phi_2 - \phi_1)} S_2$$

$$\approx 4S_1$$

Thus we successfully separate S1 and in the same way we can separate S2.

$$S_1(f_i) \approx \frac{1}{4}\begin{bmatrix} e^0 & e^{-j\frac{2\pi d cos(\theta_1)1f_i}{c}} & e^{-j\frac{2\pi d cos(\theta_1)2f_i}{c}} & e^{-j\frac{2\pi d cos(\theta_1)3f_i}{c}} \end{bmatrix} \begin{bmatrix} X_0(f_i) \\ X_1(f_i) \\ X_2(f_i) \\ X_3(f_i) \end{bmatrix}$$

$$\approx \frac{1}{4}\sum_{k=0}^{3} e^{-j\frac{2\pi d cos(\theta_1)f_i k}{c}} \cdot X_k(f_i)$$

Finally, we take the inverse Fourier transform of S_1 and S_2 to complete the separation.

$$S(f) \overset{IFFT}{\Longrightarrow} s(t)$$

2 Results

2.1 Part 1 and Part 2

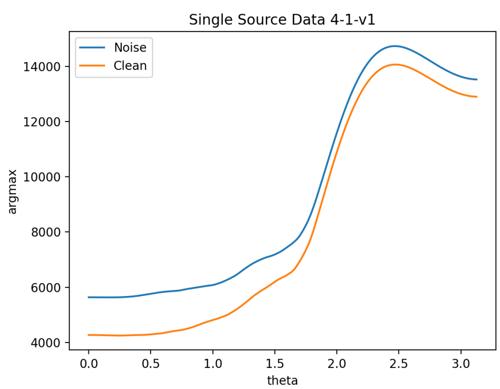


Figure 1: 4-1-v1

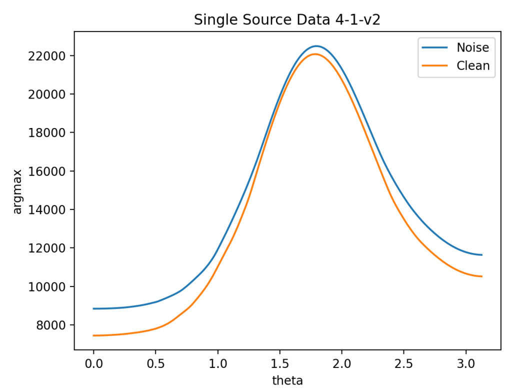


Figure 2: 4-1-v2

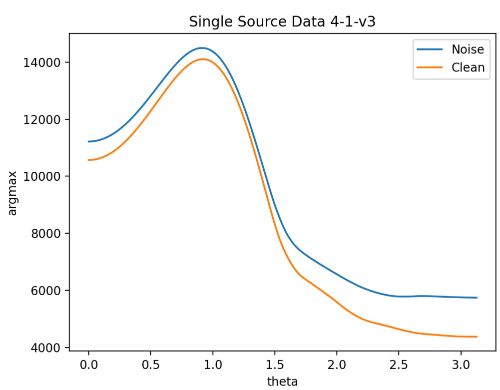


Figure 3: 4-1-v3

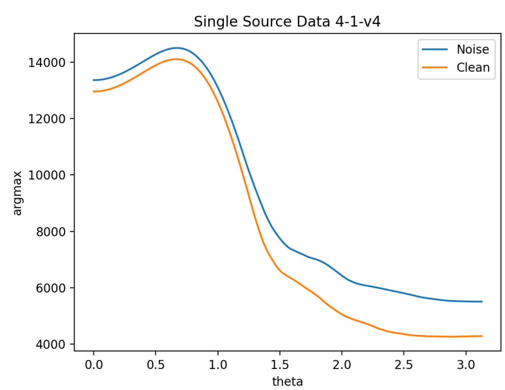


Figure 4: 4-1-v4

And the estimated AoA of each part is

	v1	v2	v3	v4
Clean	2.466	1.791	0.927	0.660
Noise	2.466	1.791	0.911	0.675

2.2 Part 3

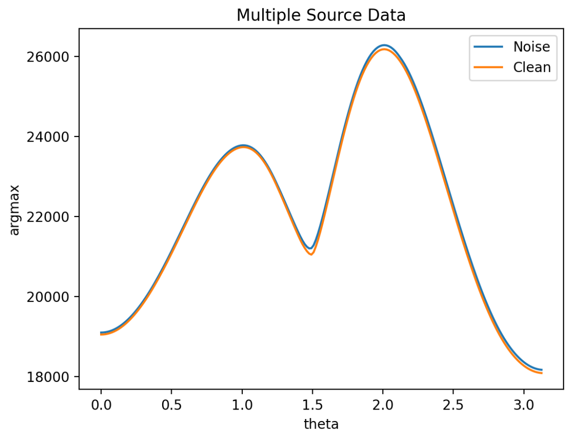


Figure 5: Multiple Source Data

And the estimated AoA is

	source 1	source 2
Clean	1.005	2.011
Noise	1.005	2.011