Direction of Arrival Estimates by Two Microphones using Matching Pursuit

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Motivation

- Do what we can do by computer
- Communication

- We can estimate some Direction of Arrivals (DOAs) using two ears.

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- We want to estimate some DOAs using two microphones.

Spatial information

- Closely located 4 points microphone method which is suggested by Prof. Yamasaki
- Signal processing using this method

- Propose the DOA estimates method using Matching Pursuit

Two microphones array

- K sounds and two microphones

$$X(\omega,t)=\begin{bmatrix}\sum_{k=1}^{K}H_{1k}(\omega)S_k(\omega,t)\\ \sum_{k=1}^{K}H_{2k}(\omega)S_k(\omega,t)\end{bmatrix}$$

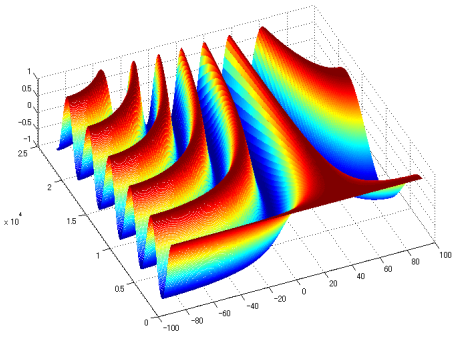
Power of Delay-and-Sum Array Output

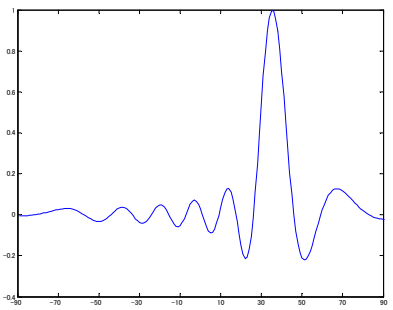
$$P(\theta,\omega) = d(\theta,\omega)^H R(\omega) d(\theta,\omega)$$

$$R(\omega) = E\left[X(\omega,t)X(\omega,t)^H\right]$$

$$d(\theta,\omega) = \left[1, \exp(-j\omega\tau)\right]^T$$

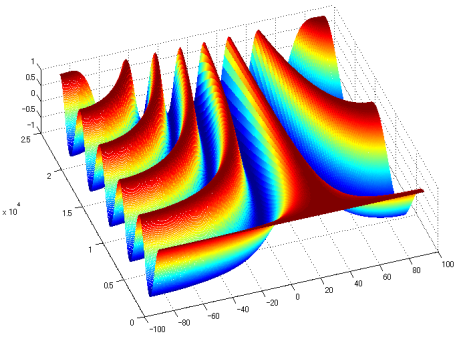
Array Output (Delay-and-Sum)

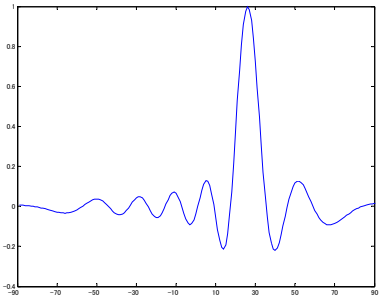




White noise source located at 34 degrees.

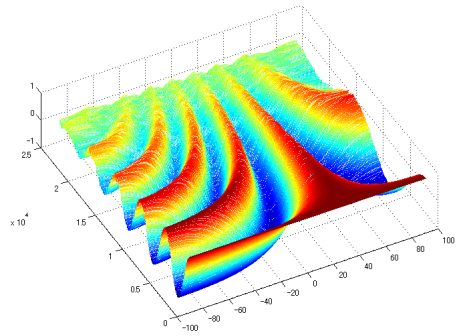
Array Output (Delay-and-Sum)

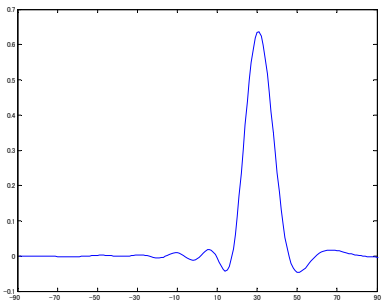




White noise source located at 26 degrees.

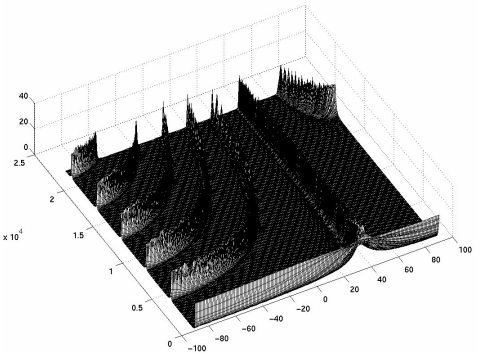
Array Output (Delay-and-Sum)

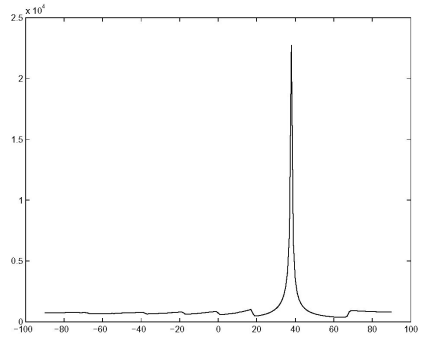




White noise source located at 26 and 34 degrees.

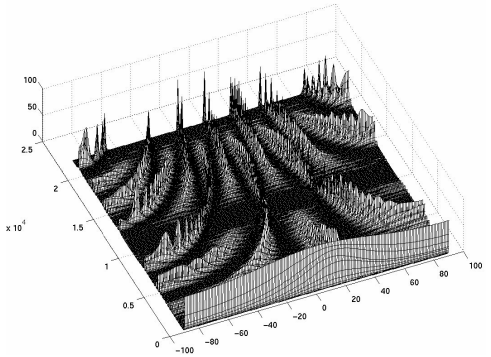
Array Output (MUSIC)

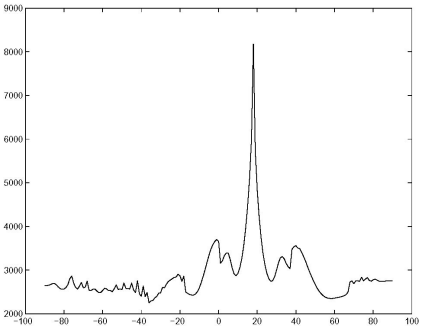




White noise source located at 38 degrees.

Array Output (MUSIC)





White noise source located at 0 and 38 degrees.

DOA Estimation

- DOA estimates for each frequency bin
- Spatial aliasing
- For many sources it is difficult.

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- DOA estimates using Matching Pursuit

Average of θ dependent component of array output over frequency bins

$$P(\theta,\omega) = P(\theta,\omega) - E[|X_1|^2] - E[|X_2|^2]$$

$$\hat{P}_{avrg}(\theta) \approx \sum_{k=1}^{K} \hat{P}_{avrg}(\theta \mid \theta_k)$$

$\hat{P}_{avrg}(\theta)$ shows the sum of the average of output for k'th sound over frequency.

→ Decompose $\hat{P}_{avrg}(\theta)$ into components $\hat{P}_{avrg}(\theta \mid \theta_k)$

Matching Pursuit

- １９９３年にMallatにより提案
- ある信号を必ずしも直交しない基底に展開する信号処理手法

- 展開に用いる基底を要素とする辞書を作成
- すべての要素に対してその成分がなくなった場合の残差を計算
- 残差を最小とする成分を抽出

DOA Estimation using Matching Pursuit

- Define a dictionary as

$$D = \left\{ \hat{P}_{avrgn}(\theta \mid \theta_k) \right\}_{-\frac{\pi}{2} < \theta_k < \frac{\pi}{2}}$$

- Calculate the residual for all direction

$$e_i(\theta \mid \theta_k) = e_{i-1}(\theta) - \alpha_{i-1}(\theta_k) \cdot \hat{P}_{avrgn}(\theta \mid \theta_k)$$

- Select

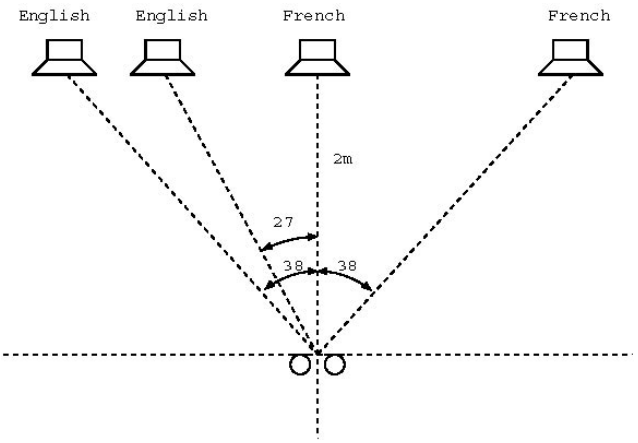
$$\hat{\theta}_i = \arg\min_{\theta_k} \sum \left| e_i(\theta \mid \theta_k) \right|^2$$

- Calculate the residual for the selected direction

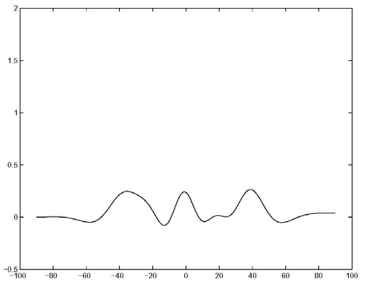
$$e_i(\theta) = e_0(\theta) - \sum_{l=1}^{i} \hat{\alpha}(\hat{\theta}_l) \cdot \hat{P}_{avrgn}(\theta \mid \hat{\theta}_l)$$

- Re-optimize DOAs using the Newton's method

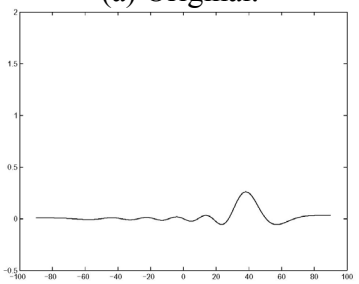
$$\Theta^{(m)} = \Theta^{(m-1)} + H^{-1}_{\Theta^{(m-1)}} g_{\Theta^{(m-1)}}$$



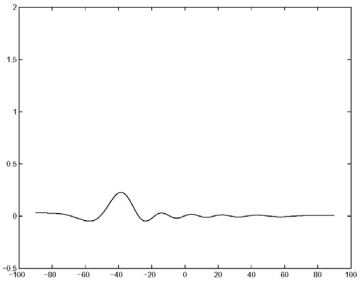
Mixture conditions.



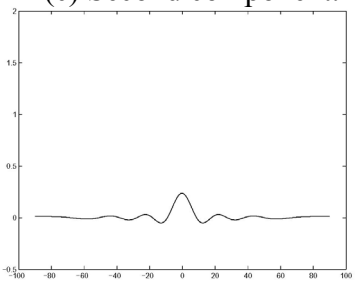
(a) Original.



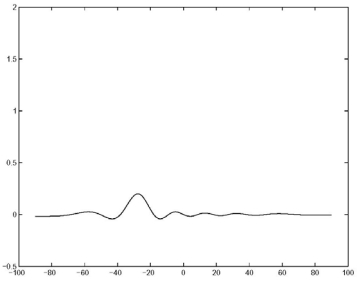
(b) First component.



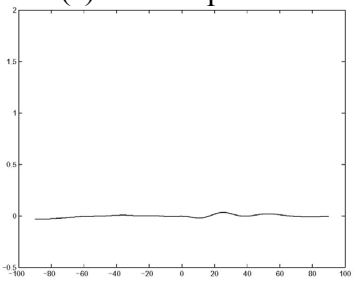
(c) Second component.



(d) Third component.

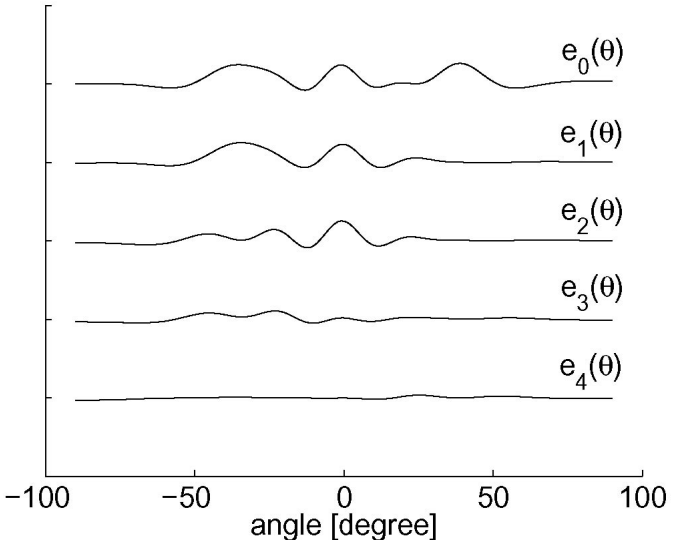


(e) 4th component.



(f) Residual.

DOA estimates.



Matching pursuit iterations.

Conclusion

- DOA estimates using Matching Pursuit
- By two microphones
- Its application to source separation.