# Real-time Fault Diagnosis Using Microphone Arrays

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## Introduction

- Use passive microphone arrays to collect acoustic signals. Implement fault diagnosis and condition monitoring by processing the signals using the state-of-art beamforming technology.
- Fault diagnosis includes learning, locating (DOA) and recognizing signals of interest from accompanying noise (See Fig. 1).
- Both spectral based and parametric beamforming algorithms are employed. Parallel computation is to applied for real-time processing.

## Experiment

- An 8-element uniform linear microphone array was made and used to collect acoustic signals.
- The array was connected to a synchronous DAC card inserted in an expansion slot in a PC running LabVIEW to collect data.
- Acoustic signals were generated from loud-speakers. Gaussian noise with varied SNR was present in addition to background noise.
- Five beamforing algorithms were used: Newton and quasi-Newton based Maximum likelihood, MODE, IQML and MUSIC.

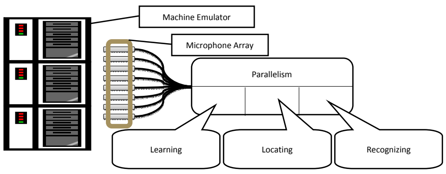


Fig. 1. Fault diagnosis using a microphone array

Fig. 2. Microphone array & data acquisition system

## Results

- Beamforming: Extract signal from noise (Fig3)
  - (a) Spectrogram of raw data from one microphone
  - (b) Eignevalue ratio of signal to noise
  - (c) Averaged spectrogram across 8 array elements
  - (d) Spectrogram after beamforming (MVDR). Signal at 3000Hz is made outstanding

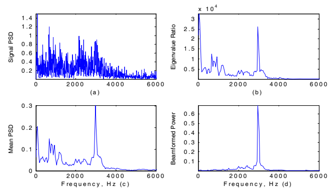

Fig. 3. Denoising

| Trial | Actual Frequency (Hz) | Estimated Frequency (Hz) | Error (Hz) |
|---|---|---|---|
| 1 | 2500 | 2490.23 | -9.77 |
| 2 | 2000 | 2001.95 | 1.95 |
| 3 | 3500 | 3491.20 | -8.8 |
| 4 | 3000 | 3002.93 | 2.93 |
| 5 | 4500 | 4492.20 | -7.8 |
| 6 | 4000 | 4003.90 | 3.9 |

Table 1. Signal Frequency Estimation

- Estimate signal frequency (Table 1)
- Number of snapshots vs estimation
  - The lower SNR, the more snapshots needed for the same estimation bias and variance (Fig. 4)
  - No clear difference among algorithms (Fig. 5)

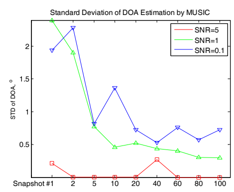


Fig. 4. DOA by MUSIC

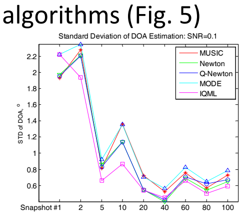


Fig. 5 By Five algorithms

- DOA estimation bias (Fig. 6)
- Moving target tracking (Fig. 7)

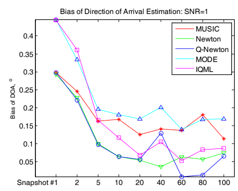


Fig. 6. Bias by 5 algorithms

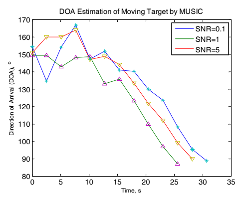


Fig. 7 DOA vs time

## Conclusion

- Minimum variance distortionless response beamforming algorithm were employed to effectively implement denoising, and determining the signal frequency.
- The minimum number of snapshots for all DOA algorithms was determined to be 20.
- The Newton ML algorithm achieved better DOA estimation performance than MUSIC, which is better than MODE and IQML algorithms.