Problem Statement

Sound signature classification has been suggested as a feasible method for monitoring elderly people in their homes and superior to video cameras which introduce privacy concerns. If an elderly person’s activities of daily living can be detected from which a picture of their routine obtained, important information regarding their function health status could be derived. In this thesis a two microphone sounds of daily life (SDLs) classification system has been developed and included the design and implementation of novel noise reduction algorithms.

1. Proposed Solution

Training (clean data)

- SDL Activity Detection (energy)
- Calculate Features (MFCC + SDC)
- Train Model (GMM)

Testing (noisy data)

- Calculate SAD Activity
- Merge Signals
- Calculate Features (MFCC + SDC)
- SDLs

Means and standard deviations (MAP Adaptation)

Figure 1: Block diagram of system evaluation method

• Features (compact representation of a signal useful for distinguishing between SDLs) extracted using Mel frequency cepstral coefficients (MFCCs) and shifted delta cepstrum (SDC)
• Gaussian mixture model (GMM) models an arbitrary probability density function and is used for classification
• Baseline technique – selects best channel by estimating SNR by finding SDL and noise segments using a standard SAD algorithm

2. Proposed Signal Enhancement Algorithms

Independent component analysis (ICA) separates mixture of SDLs and noise in microphone signals. The central limit theorem suggests the microphone signals will be more Gaussian than the component sources. ICA estimates the separation matrix \( \mathbf{W} \) which minimises the Gaussianness of the separated sources:

\[
\mathbf{s}_{\text{sep}}[n] = \mathbf{W} \mathbf{s}[n]
\]

ICA has been extended by choosing the separated source with the best signal to noise ratio (SNR):

\[
\tilde{s}_{\text{kitchen}}[n] = \begin{cases} 
\mathbf{s}_{\text{sep}}[n] & \text{if } \text{SNR}\left(\mathbf{s}_{\text{sep}}[n]\right) > \text{SNR}\left(\mathbf{s}_{\text{sep}}[n]\right) \\
\mathbf{s}_{\text{sep}}[n] & \text{if } \text{SNR}\left(\mathbf{s}_{\text{sep}}[n]\right) > \text{SNR}\left(\mathbf{s}_{\text{sep}}[n]\right)
\end{cases}
\]

SNR steepest ascent (SSA) is an adaptation from ICA. Sets separation matrix coefficient \( b_{12} = 1 \) and adapts \( b_{12} \) using a steepest ascent approach to maximise the SNR.

Figure 2: Variation of the SNR for as \( b_{12} \) varies. The goal is to reach the peak SNR.

The coefficient \( b_{12} \) is adapted according to:

\[
b_{12} = b_{12} + \mu \frac{\partial \text{SNR}}{\partial b_{12}} \text{ where } \mu \text{ is a constant}
\]

4. Sounds of Daily Life (SDL) Database

- Data recorded in a quiet environment for training and comparison
- SDLs in the presence of noise (a radio, male speaker and rain) also recorded
- Noise recorded from an internet radio station mixed into clean data (perfectly correlated noise)
- Microphone 1 – primary channel and microphones 2, 3 and 4 – secondary (to compare placements)
- Similar ideal database also recorded using two microphones with one microphone close to radio
- Range of SNRs – 0 – 32 dB
- Contains 4 hours and 20 minutes of data

Figure 3: Example time-frequency plot of largest eigenvalues from 3 – 4 kHz

5. Evaluation

Table 1: Experimental results from SDL classification system

<table>
<thead>
<tr>
<th>Technique</th>
<th>Database</th>
<th>Accuracy</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSLE</td>
<td>Ideal</td>
<td>100%</td>
<td>35.50%</td>
</tr>
<tr>
<td>CSLE</td>
<td>Radio Mic 1 &amp; 3</td>
<td>84.08%</td>
<td>32.83%</td>
</tr>
<tr>
<td>ICA + CSLE</td>
<td>Talking Mic 1 &amp; 3</td>
<td>81.67%</td>
<td>37.06%</td>
</tr>
<tr>
<td>CSLE</td>
<td>Rain Mic 1 &amp; 3</td>
<td>99.77%</td>
<td>38.06%</td>
</tr>
</tbody>
</table>

SSA improved relative reduction in error rate by 17.90% when noise was mixed into two microphones at 20 and 15 dB.

6. Conclusion

This thesis proposes a solution to accuracy degradation when classifying SDLs in noisy environments. Algorithms mean SDLs can now be classified in many realistic situations with a high level of accuracy. Key contributions are:

- CSLE best algorithm – improves accuracy on all databases
- Highest improvement – 38.06%
- SSA improves on ICA when noise is highly correlated
- SSD more effective for noise reduction than signal enhancement