Snore Sound Separation of Enlarged Adenoid From Normal Heart Sound using Blind Source Component Separation Method

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ABSTRACT
Enlarged Adenoids is a disease which results in the blockage of air passage of infants. These babies who are infected with adenoids will produce high snoring sounds while they sleep. For children suffering from adenoid, it's a heart breaking scene for a parent to see their small innocent baby could sleep only in a sitting position. The sound of snore produced by such babies is too loud, that it can reach a person at several meters away from the baby. When there is a blockage of air passage due to flu, the snore sound of baby will go high. The adenoid snore sound infected by flu may mislead diagnosing. Here we propose a technique using Degenerate Unmixing Estimation Technique to separate the adenoid snore sound and normal heart beat sound while doctor examines a sleeping baby, with a case of enlarged adenoids. The snore sound is a noise which needs to be separated to get a clear rhythm of heart sound.

General Terms
Blind Source Separation using Degenerate Unmixing Estimation Technique is used here for separation Adenoid snore sound and normal heart beat sound.

Keywords
Blind Source Separation, Adenoid, DUET Algorithm, Heart Sounds.

1. INTRODUCTION
Blind source separation (BSS) refers to the method of recovering two or more sources from a number of unknown mixtures. Signal mixtures are available everywhere.

Blind signal separation relies on the assumption that the source signals do not correlate with each other. The scenario of this problem was to let two people talking simultaneously in two microphones placed some distance apart from each other. An adaptive algorithm would then separate the speakers, despite the fact that their speech is within the same frequency range and that no explicit desired signal is available to control the adaption. This problem is sometimes referred to as the "coctail party" problem. This is shown in Figure1.

Figure 1. shows the coctail party problem and the inability of the human auditory system to separate out a single speech source

Basically there are two different approaches to this problem. A Bayesian approach to Independent Component Analysis (ICA) had been used to separate the static linear mixtures. ICA solution to the audio source separation which required one microphone to each number of sources is shown in Figure.2

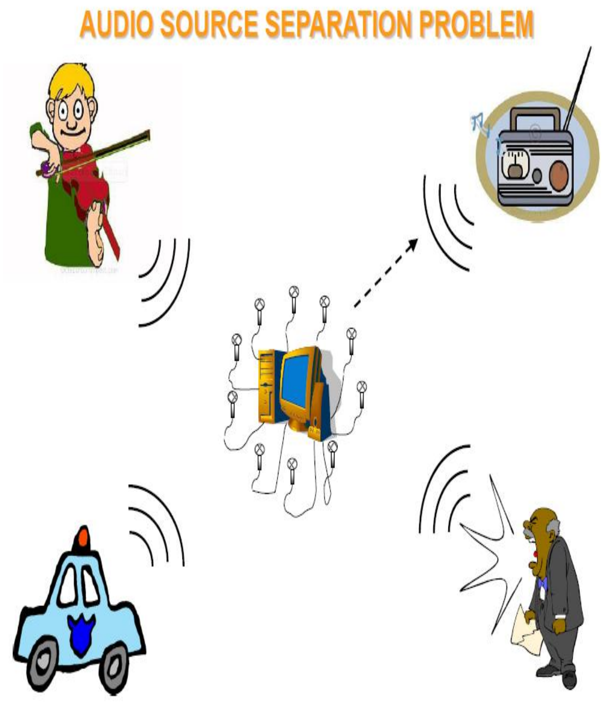

Figure 2 shows ICA solution to the audio source separation which required one microphone to each number of sources.

The assumption of DUET algorithm lies in the disjoint representation of sources in frequency domain. DUET algorithm for cocktailparty problem is shown in Figure 3.

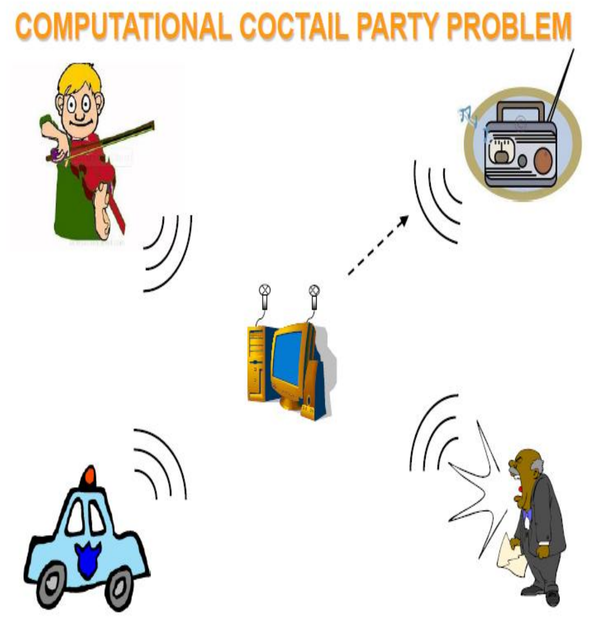

Figure3 shows the DUET solution to the cocktail party problem which requires only two microphones for any number of sources.

The performance of DUET algorithm is better than Independent Component Analysis. The number of microphones required for DUET algorithm is less when compared to ICA. So we choose DUET algorithm for blind source separation problem. Mixing Procedure in DUET algorithm is shown in Figure 4.

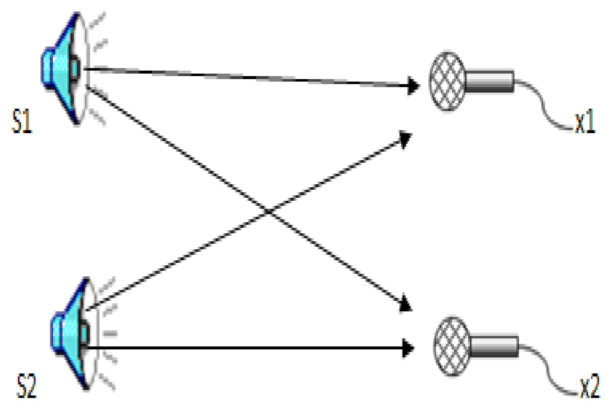

Figure 4: Mixing Procedure in DUET algorithm.

The Short-Time Fourier Transform (STFT) provides a means of time-frequency analysis .In Matlab, it can be implemented as a windowed FFT. The inverse of the STFT can be implemented as inverse FFT.

Author has come across a case where enlarged adenoid snore sound was misdiagnosed by doctors and the baby was taken for serious treatments. These treatments made the baby's skin complexion to change from fair to dark colour. Too many medicines and around forty injections were given to a sixty nine day old infant without diagnosing the baby's enlarged adenoid disease. The baby who was active earlier, became too tired after consuming the medicines. But the doctors continued to give stronger medicines. This is one of the incidents that motivated the author to separate the enlarged adenoid snore sound and normal heart beat produced sound. The enlarged adenoid sound is too high when the baby infected by any allergy or flu. This allergic conditions may block the nasal passage and air gap for breathing will be reduced, which will lead to an amplified sound as the baby breathes.

Researchers have studied about size of adenoid and the snoring intensity[1]. Hypertrophic adenoids may affect the resonance of speech sound [2]. Respiratory disturbances during sleep time due to adenoid-tonsillar hypertrophy, has been studied[3]. Body position and obstructive sleep apnea in 8–12-month-old infants has been studied [4].Chronic Snoring and Obstructive sleep Apnea syndrome has been discussed [5].

To the best of our knowledge, we have not come across oonsiderable research work which evaluates separation of sounds of enlarged adenoid snore sound and normal heart beating sound.

In this paper, the problem considered is the separation of enlarged adenoid snore sound and normal heart sound signals. It uses degenerate unmixing estimation technique, which uses a two microphone approach. This is represented in Figure 5.

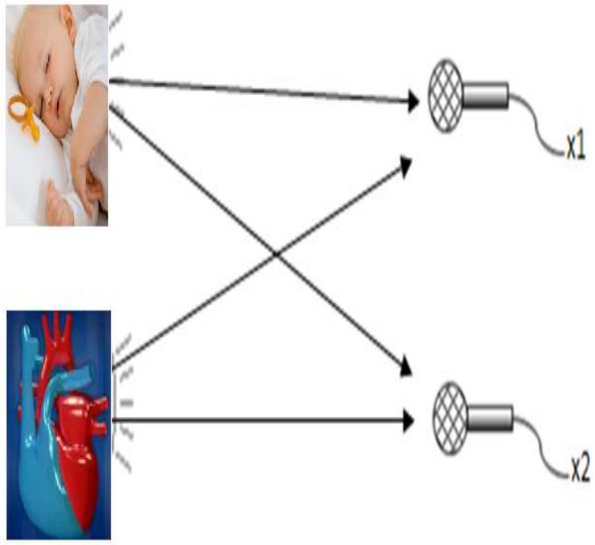

Figure 5: DUET Technique for separation of enlarged adenoid Snore sound and normal heart beat.

In section 2 we explain about enlarged adenoids. In section 3 we discuss snoring and its causes. due to enlarged adenoids. In Section 4 we introduce the size of adenoid tissue and explain how it produces snoring by blocking the air passage. In the sections following from section 5 onwards, we have discuss how to apply the technology to separate the normal heart sound and enlarged adenoid tissue caused baby's snore sound. Results has been given at the end of the section.

2. ENLARGED ADENOIDS

The adenoids are lumpy clusters of spongy tissue that help protect kids from getting sick. The adenoid glands sit behind your nose above the roof of your mouth. Air passes over these glands when you take a breath. Although you can easily see your tonsils by standing in front of a mirror and opening your mouth wide, you can't see your adenoids this way. A doctor has to use a special telescope to get a peek at your adenoids. Enlarged adenoids are swelling of the lymph tissue found in the airway between your nose and the back of your throat. The tissue is similar to the tonsils. The enlarged adenoids can be best diagnosed by using fiberoptic endoscopic method which is shown in photograph of Figure 6

3. SNORING

It may be hard to believe, **a** sleeping, innocent baby is capable of big, raucous snores. Someone so small and adorable will produce such loud and grating noise. Snoring happens when there is a blockage of airflow through a toddler's nose and throat. This is due to an enlarged adenoid. The snore sound we hear is the vibration of structures in the mouth and throat rubbing against one another as child breathes. If a baby is snoring the nights away, it's best to have him checked by your pediatrician, especially if the snoring is coupled with breathing problems.

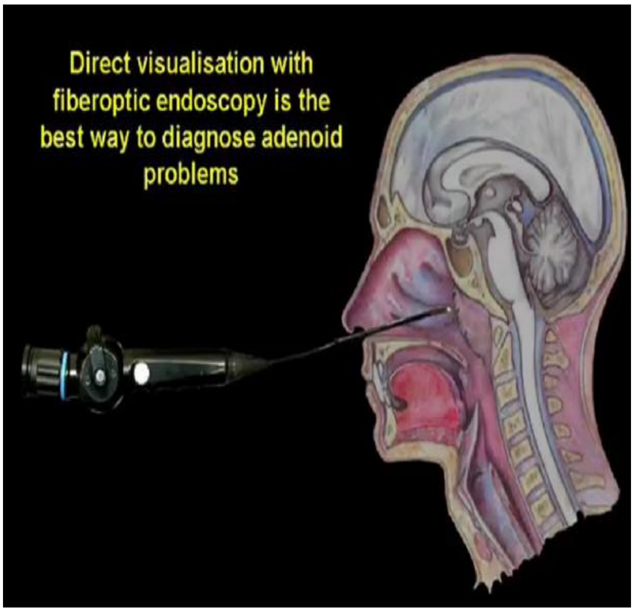

Figure 6: Fiberoptic endoscopic method to diagnose enlarged adenoids

3.1 CAUSES OF SNORING

Colds, flu, and allergies may be a reason for snoring. Upper-respiratory infections are the culprits behind most bouts of occasional snoring in kids. It happens when your child's nose gets stuffed up and mucus blocks his airway, creating turbulence in the airflow as it passes through the throat. Since allergies can cause congestion, they also may cause snoring.

Enlarged adenoids may be a natural occurrence, beginning when the baby grows in the womb. The adenoids are lumpy lymph tissue located where the nose meets the throat, and the tonsils are two lumps of lymph tissue located at the back of the throat. Both adenoids and tonsils guard your child from infections by trapping inhaled viruses and bacteria. In the process, though, they sometimes become infected and swollen. Enlarged adenoids and tonsils can get in the way of airflow and cause snoring.

If the loud snoring is interrupted by pauses in breathing, infant may have obstructive sleep apnea (OSA), a serious condition in which air can't get through to the lungs. Obstructive sleep apnea is a condition in which the flow of air pauses or decreases during breathing while you are asleep because the airway has become narrowed, blocked, or floppy. The pauses in breathing can last for ten seconds or more, and they can happen many times throughout the night. This can be dangerous, and it can break up toddler's sleep, causing him to be grumpy, experience extreme fatigue, headaches, and growth problems. Most cases of OSA in this kids are caused by enlarged adenoids or tonsils.

4. SIZE OF ADENOIDS

The Swollen or enlarged adenoids are common. When this happens, the tonsils may also get swollen, too. Swollen or infected adenoids can make it tough to breathe and cause these problems:

- a very stuffy nose, so a kid can breathe only through his or her mouth
- snoring and trouble getting a good night's sleep
- sore throat and trouble swallowing
- swollen glands in the neck
- ear problems
- Produce high snore sounds that will be accompanied as noise while doctor examines a baby's chest, during the babies sleeping time.

A graph showing a relative sketch of size of adenoid tissue as the age moves up is shown in Figure 7. The enlarged adenoid tissue is shown in photograph of Figure 8. The airway due to enlarged adenoids blocks the airway. This is shown in photograph of Figure 9 .

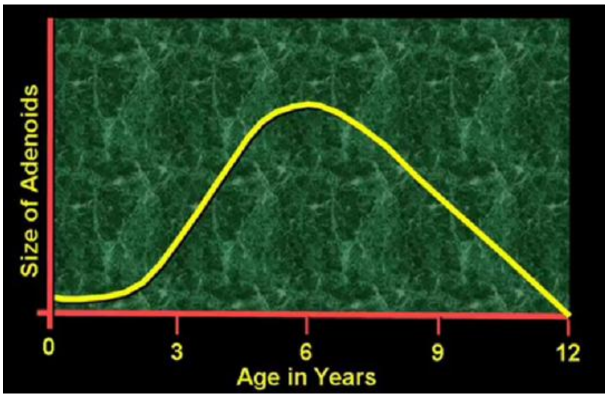

Figure 7: Age and size of Adenoids

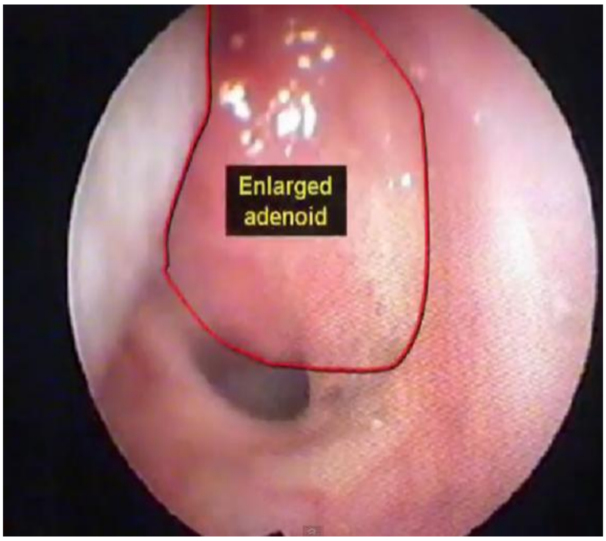

Figure 8: Photograph showing enlarged adenoids

Figure 9: Photograph showing the airway path narrowing due to enlarged adenoids, which results in high snore sound.

5. CONTRIBUTION OF TECHNOLOGY

The snore sound of an enlarged adenoid sound is annoying while examining chest of a baby with enlarged adenoid. If a baby with an enlarged adenoid is affected by flu and taken to a doctor, the snore sound of baby will be high. If the baby was not diagnosed earlier of enlarged adenoids, the sound may threaten and misguide the doctor. Instead of flu, the innocent baby may be treated for pneumonia. We use this sound separation technique, to avoid misdiagnosis. A noise free heart sound is important while examining a baby's chest. The enlarged adenoid infected baby's snore sound is usually a noise while examining the heart beats with stethoscope. The separation of adenoid snore sound and heart beat is done here using blind source separation with the help of Degenerate unmixing estimation technique. It is best to have a noise free heart beat to know about the intensity of a disease. We also obtained the separated snore sound of enlarged adenoid tissue.

6. DEGENERATE UNMIXING ESTIMATION TECHNIQUE

Blind Source Separation (BSS) deals with the problem of separating unknown mixed signals without prior knowledge of the signals. In this paper, mixed snore sound of enlarged adenoid case and heart sounds are used in the derivation and experiments. Here we used artificial delayed mixing technique to capture the adenoid snore sound and heart sound by two microphones placed some distance apart from each other. An adaptive algorithm would then separate the sounds, despite the fact that their frequencies should not be in the same range. Early on in the project the Degenerate Unmixing Estimation Technique (DUET) was found while investigating new approaches to the problem [6]. DUET was decided to be more interesting because it performs source separation by frequency domain processing and is independent of the number of mixed sources. All efforts are put into implementing DUET in Matlab.

6.1 Algorithm

To introduce the DUET algorithm a model for describing the mixing of sources is established. The specific example of two microphone channels is taken. The sources, which in our case is represented by the snoring sound produced by an enlarged adenoid tissue and normal heart beat. Both these signals are captured as shown in Figure.10

The DUET algorithm operates in the frequency domain. No inverse matrix is calculated and it is one of the reasons it shows very good performance. Another bonus compared to Bayesian Independent Component Analysis is that the number of sources can be greater than the number of mixtures; in fact it can be used for an arbitrary number of sources. The DUET algorithm [7], which has been developed especially with a real-time implementation in mind is modified in order to incorporate variable time frequency resolution.

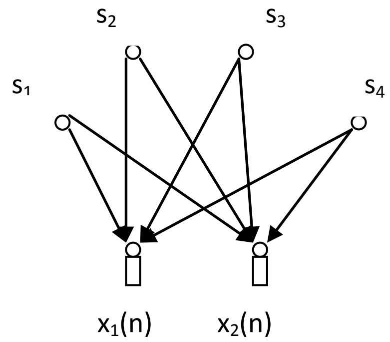

Figure 10: Two-channel microphone arrangement with multiple sources . Here four sources are shown. Two microphone arrangements are used in DUET Technique for sound separation.

7. DUET TECHNIQUE

A version of the online DUET algorithm was chosen to be implemented because of the good results presented in [7]. There are many fields where Blind Source Separation could be useful, e.g. separation of radio signals in telecommunication, separation of brain waves from medical sensors or in audio applications as in hearing aids or for demixing stereo recordings [8]. It is fast and the implementation is about 5 times faster than real time. It separates an arbitrary number of sources from a set number of mixtures. For a two-channel microphone arrangement with K sources, the incoming mixed signals x1 and x2 can be described as

$$x_1(n) = \sum_{j=1}^{k} s_j(n) \tag{1}$$

$$x_2(n) = \sum_{j=1}^{k} a_j s_j(n-\delta_j) \tag{2}$$

The mixtures x_1 and x_2 are sampled and split into blocks of length N with overlap. These sample blocks are multiplied with a windowing function W and then Discrete Fourier Transformed to

$$\overset{\theta}{x}_{1,2}(n) = W(n)\, x_{1,2}(n) \tag{3}$$

$$X_{1,2}(k) = \sum_{n=0}^{N-1} \overset{\theta}{x}_{1,2}(n)\, e^{-j2\Pi nk/N} \tag{4}$$

In each of the sample blocks in the frequency domain,the frequencies are determined and the minimum difference,Δf between these frequencies are determined.The width of the window size is determined by this difference Δf.The window width allotted will be greater for blocks having lesser Δf and narrower for blocks having greater Δf.Thus the time-frequency resolution is adaptively changed according to the frequencies present in each sample blocks.

Transforming the mixtures gives us a spectrogram with a two-dimensional time-frequency grid. Since $x_1(n)$ and $x_2(n)$ consists of a mixture of the original sources $s_j(n)$, transforming the mixtures means that the sources now also have undergone a Short-Time Fast Fourier Transform (ST-FFT). Let the Fourier transform of the sources be Sj(ω). For a given source j we can describe the ST-FFT of (1) and (2) as

$$\begin{bmatrix} X_1(\omega) \\ X_2(\omega) \end{bmatrix} = \begin{bmatrix} 1 \\ a_j e^{-j\omega\delta_j} \end{bmatrix} S_j(\omega) \tag{5}$$

The DUET algorithm is based on the basic assumption that all of the sources have a different frequency spectrum for any given time. This implies that each time-frequency point in the spectrogram shown in Fig. 4 is associated with only one source. This property, which is essential for the DUET algorithm, is called the W-disjoint orthogonality property and is described as in the equation given below.

$$S_i(\omega) S_j(\omega) = 0 \ \forall\ i \neq j \tag{6}$$

To find the parameters in the online DUET algorithm, Maximum Likelihood (ML) gradient search is used. Let us define

$$\rho_j(\omega) = \frac{1}{1+a_j^2}\left| X_1(\omega) a_j e^{j\omega\delta j} - X_2(\omega)\right|^2 \tag{7}$$

We can see that for any given source j there is a function α_j , which is zero for all frequencies that belongs to j. That is

$$\rho_j(\omega) = 0 \tag{8}$$

As shown in [2] the smooth ML objective function is given by

$$J = \min_{a_1\delta_j} \sum_{\omega} \frac{-1}{\lambda} \ln(e^{-\lambda p_1} + e^{-\lambda p_2} + \ldots\ldots + e^{-\lambda p_k}) \tag{9}$$

where λ is the amplification factor.

and the partial derivative of J with respect to δ_j is

$$\frac{\partial J}{\partial \delta_j} = \sum_{\omega} \frac{e^{-\lambda p_1}}{\sum_{r=1}^{k} e^{-\lambda p_r}} \cdot \frac{2}{1+a_j^2} \cdot \omega a_j \cdot$$
$$\cdot(\mathrm{Im}\{X_1 e^{j\omega\delta_j}\}\mathrm{Re}\{X_2\} - \mathrm{Re}\{X_1 e^{j\omega\delta_j}\}\mathrm{Im}\{X_2\}) \tag{10}$$

and the partial derivative of J with respect to aj is

$$\frac{\partial J}{\partial a_j} = \sum_{\omega} \frac{e^{-\lambda p_1}}{\sum_{r=1}^{k} e^{-\lambda p_r}} \cdot \frac{2}{1+a_j^2} \cdot$$
$$\cdot (a_j |X|_1^2 - a_j \rho_j - \mathrm{Re}\{X_1 e^{j\omega\delta_j}\} \mathrm{Re}\{X_2\} - \mathrm{Im}\{X_1 e^{j\omega\delta_j}\} \mathrm{Im}\{X_2\})$$

(11)

These partials were recalculated, since the algorithm given in [5] failed to function .

The number of sources in the mixtures is assumed to be known and an amplitude a_j and a delay δ_j estimate for each source are initialized. The parameters a_j and δ_j are updated based on the previous estimate and the current gradient as

$$a_j[k] = a_j[k-1] - \beta \alpha_j[k] \frac{\partial J}{\partial a_j} \qquad (12)$$

$$\delta_j[k] = \delta_j[k-1] - \beta \alpha_j[k] \frac{\partial J}{\partial \delta_j} \qquad (13)$$

where β is the learning factor and $\alpha_j[k]$ is a time and mixing parameter dependent learning rate for time index k and estimate j. The mixing energy can be described as

$$q_j[k] = \sum_{\omega} \frac{e^{-\lambda p_1}}{\sum_{r=1}^{k} e^{-\lambda p_r}} |X_1| \cdot |X_2| . \qquad (14)$$

and define

$$qs[k] = \gamma qs[k-1] + q[k] \qquad (15)$$

where γ is the forgetting factor. This allows us to write the parameter dependent update rate $\alpha_j[k]$ as

$$\alpha_j[k] = \frac{q[k]}{qs[k]} \qquad (16)$$

We know that ρ_j is minimum for any given time-frequency point that belongs to sj . If this is not the case, the time-frequency point belongs to another source. We can therefore construct a time frequency mask based on the ML parameter estimator.

$$\Omega_j(\omega) = \{1 \ \forall \ \rho_j(\omega) \le \rho_m(\omega) \quad , m \ne j$$
$$= \{ 0 \qquad \text{otherwise} \qquad (17)$$

Now extract the discrete time Fourier transform estimate of the j[th] source from mixture $X_j(\omega)$

$$\tilde{S}_j(\omega) = \Omega_j(\omega) X_j(\omega) \qquad (18)$$

At this point we have performed the signal separation and all that is left to do is to compute our windowed source estimate using the inverse Discrete Fourier Transform

$$\tilde{S}_j^{\theta}(n) = \frac{1}{N} \sum_{n=0}^{N-1} \tilde{S}_j(k) e^{\frac{j2\Pi nk}{N}} \qquad (19)$$

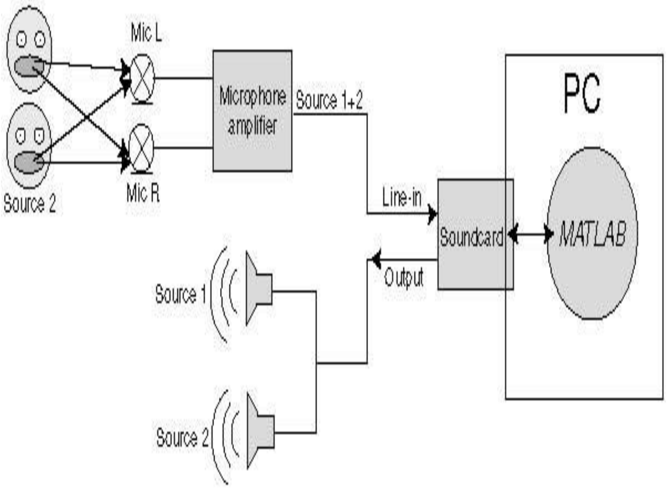

Figure 11 : Experimental set up for two sources .

7.1 Experiments

Since the algorithm required input from two microphones simultaneously, these were connected to the line-in input of the soundcard via a microphone amplifier, so that one microphone connected to the left channel and the other one to the right channel. Matlab was used to capture the audio signals from the line-in input, separate the sources and output the separated data to the soundcard, according to the block diagram in Fig. 11. Here were obtained this by artificial delayed mixing technique.

7.2 Matlab implementation of DUET algorithm

The algorithm is written in Matlab 6.5 and was run on a PC. It works by taking a two-channel wav-file, with one mixture per channel, and reading it, or part of it, into an array. The program could easily be modified to take samples directly from the soundcard. It then takes 1024 samples at a time from this array and the Fast Fourier Transform (FFT) for this set of samples is calculated. Once this is done we can estimate the parameter changes and update the parameters using equations given. After updating the parameters, we can separate the signals from this block using a binomial mask as in the equation given. The separated two-channel array is then either saved to a wav-file or played by the soundcard. We then wait, if needed, until the buffer has enough elements and start over with the next 1024 samples. This process is repeated until the whole file has been demixed.

To facilitate sound recording, analysis of results and saving of separated data, developed a Graphical User Interface (GUI) for the Blind Source Separation application. This was done by using the user interface editor guide in Matlab.

In the Input source box, the user can choose whether to use audio data from a sound file or to perform a live recording from the soundcard. The user can also change other settings concerned with recording and playback of audio data. After pressing the Start separation button, the input data is acquired either from a file or the soundcard. Thereafter the algorithm separated the sources in real-time. After the separation is done, the amplitude difference and time delay between the sources are plotted in the window.

7.3 Parameters

The following parameters were used during experiments; $\gamma = 2$, $\beta = 0.1$ and $\alpha = 0.2$ where γ is the amplification factor, β is the forgetting factor and α is the learning factor. As a windowing function a rectangular window was used. It was found that different window-functions did not produce noticeably different results, but that the FFT size was important.

7.4 Demixing of Artificial Mixtures

Fiberoptic endoscopy is used to find enlarged adenoids. Fiber optic endoscopic equipment, which uses light rays is shown in Photograph of Figure 12.. A doctor examining a kid for enlarged adenoid disease is shown in photograph in Figure 13.Visualisation of enlarged adenoid in screen by experts is shown in photograph of Figure 14.

Figure 12:Part of Fiber optic endoscopic equipment, light rays are seen in photograph.

Figure:13. Doctor using fiberoptic endoscopy in a kid to diagnose enlarged adenoid disease.

Figure:14. Doctors visualizing enlarged adenoids with fiberoptic endoscopy.

To get source mixtures of snore sound and heart beat sound audio files, the Matlab function wavread was used, to read the contents of a file into an array. By mixing two arrays it was able to get a mixture, which could be tried to separate block-wise in real-time. The resulting demixed signals were saved into new arrays which could be stored to file using wavwrite.

The mixed enlarged adenoid snore sound and heart beat sound is captured by a two microphone arrangement. The enlarged adenoid snore sound is separated from normal heart sound .

8. RESULTS

8.1. Demixing of Mixtures

The algorithm was able to demix all mixed audio files. The algorithm was implemented for two sound mixtures. The files were read separately and mixed within Matlab. The algorithm converges very fast and the best separation contains almost no trace of the other source. In this, as mixtures, the mixed signals used were, enlarged adenoid snore sound and a normal heart beat sound . The amplitude difference and time delay plots of real mixtures were also obtained . Separated mixtures are shown in Figure 15 and Figure 16.

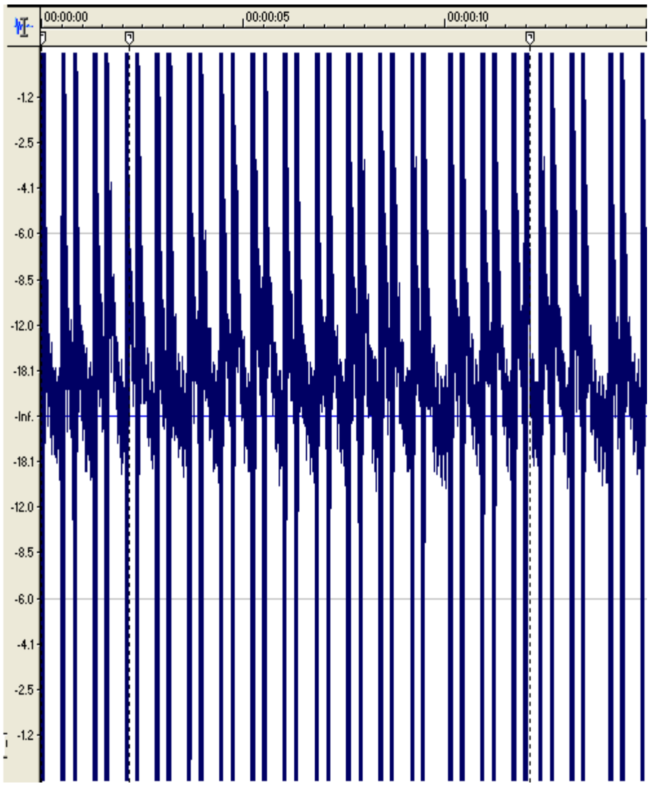

Figure 15: Normal heart sound separated signal

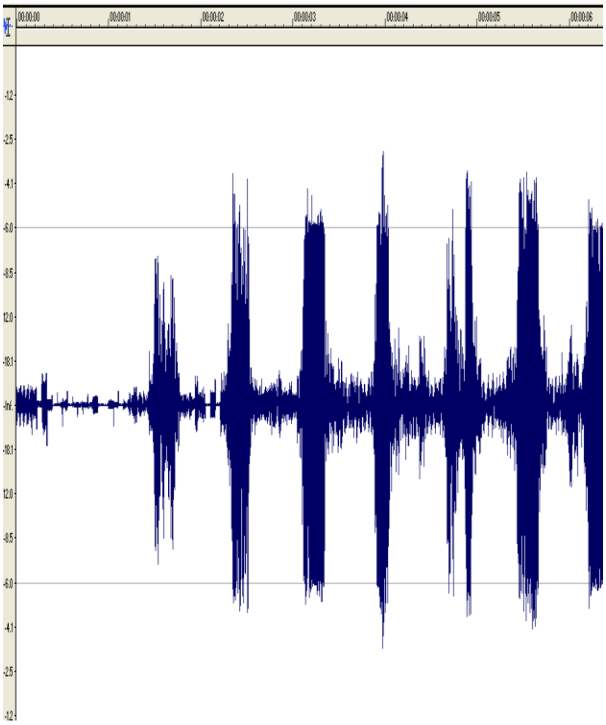

Figure 16: Enlarged adenoid tissue infected baby's snore sound separated signal

9. CONCLUSION

The focus of this paper is on blind source separation applied to enlarged adenoid snore sound and normal heart beat sound signals. The Degenerate Unmixing and Estimation Technique is used for this purpose. The approach utilizes binary time-frequency masks as tools for source separations. This paper demonstrates the powerfulness of the *basic* DUET approach that uses a simple intuitive idea to estimate the mixing parameters, and the powerfulness of time-frequency masks as an efficient tool for signal separation. A version of the degenerate unmixing estimations technique (DUET) algorithm is implemented in Matlab. The implementation was tested by artificial delayed mixing of enlarged adenoid sounds and normal heart beat sounds. We were able to obtain good separated result for the signals.

10.FUTURE ENCHANCEMENT

The original implementation of the method was carried out by using STFT which results in some loss of Information .This can be avoided by using wavelet transform. Some of the fields of future research can include

- Separation of brain waves from medical sensors.
- Separation of radio signals from telecommunication devices.
- Demixing stereo recordings for hearing aids .

11. ACKNOWLEDGMENTS

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