# ACTIVE NOISE REDUCTION USING WAVELET TRANSFORM

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## ABSTRACT

This study focuses on Active Noise Reduction Using Discrete Wavelet Transform. Noises emanating from electric drill, pneumatic system, bearing of rotating motors and many others, can be classified as non-stationary signals. These examples of noises typically coming from machine shops contributes to the interference of desired signals. The objective of this study is to provide a system that simulates how to reduce unwanted signal generated by electrical system noise. In order to perform this task, a recorded voice and noise were processed by wavelet transform to get the wavelet coefficients of signals. In this research, detail and approximation coefficient values were used for filtration algorithm. The algorithm was then customized to specific voice characteristic. For the reduction of noise, a Discrete Wavelet Transform (DWT) was applied for signal processing. Different wavelet such as Daubechies Wavelet Transform Db02, Db04 and Db08 however were used to test its effectiveness. Signal-to-noise ratio formula was used to validate if the reconstructed signal is identical with the uttered voice. Graphical programming Language of Laboratory Virtual Instrumentation Engineering Workbench (LABVIEW) was utilized to manage a number of simulation experiments for validation. Industrial power tool producing noise such as grinder, power drill, single phase motor, vacuum cleaner and welding machine were used as a source of generated noise. In the reconstruction of filtered output, Inverse Wavelet Transform was utilized for the reference-desired signal to verify the algorithm for noise cancellation. It is found that DB02 provides better results for the combination of voice-vacuum cleaner and voice-welding machine, DB04 is better for voice-grinder combination while DB08 had better noise reduction to voice-power drill and voice –single phase motor.

## 1. 0 INTRODUCTION

Passive and Active noise cancelling headphones are the two methods used in filtering unwanted sound and it is also being used in some machine shop environment to help the operator in avoiding distracted noises that could cause hearing impairment. Passive noise for cancelling headphones uses earmuffs made in high density foam with leather to block out

external noise, but this method prevents communication with other operators. The active noise cancellation is effective in reducing noise.

The design is customized to a certain voice and such customization is possible using wavelet transforms. The Labview by National Instrument provided effective techniques in customization simulation. The test case for noise is the noise generated by an electric drill. Wavelet analysis is the method of decomposing signals into different sub-band to provide higher degree of details of the given signal wherein the programmer can easily eliminate certain frequencies of signal arbitrarily. Acoustic noise can contained high and low frequency which can be analyzed and displayed both in time and frequency domain at the same time. The visual illustration of signal characteristic in term of time and scale (frequency domain) helps defined the algorithm for manipulation of wavelets coefficients. Wavelet Multi-Resolution Analysis is used to design the electric drill noise cancelation algorithm.

## 2. 0 REVIEW OF RELATED LITERATURE

### Noise

Noise is a disruptive signal that is random in nature, and it originates externally from the system. In theory noise is directly proportional with the wavelength and inversely proportional with the frequency (Cazagui Diana, 2013). Excessive noise is harmful a simple use of headphones will cause hearing loss over loud volumes this is the same in effect by industrial machines (Nagarajan & Narayanamoorthi, 2015). According to ISO (International Organization for Standardization), standard exposure to noise induced sound level must be cut by half in every 3 decibel increase in sound level. The instensity of sound is characterized by the vibration, which is measured in decibles (dB). It is a special unit in logarithm (log), unlike linear scale, each decibles is larger than the values that measures before it. For example a 20 decibel is ten times larger than 0 dB while 100 dB is 100,000 larger and son on. A conversational speech at 3 ft distance can be measured 60 dB, while a jet engine at 9 ft away measures 140 dB. At this level, it can harm someone's ear which results to temporary or permanent hearing loss (Dalebout, 2008). The National Institute for Occupational Safety and Health (NIOSHI) published a guideline for person's daily exposure which should not exceed to 85 dB for hours a day which follows through by the 3 dB safe exposure time which should be cut to one-half. For example, 88 dB is allowed if exposure time will not exceed to 4 hours, while 91 dB is permissible if exposure time will not exceed to 2 hours, and so on. A 115 dB sound level, exposure or greater should be avoided to prevent hearing loss. Keep in mind that the louder the noise, the shorter the accepted safe exposure time. However there are no regulations protecting a person against hazardous noise environment. As a rule of thumb, noise can be dangerous if ears hurt during or after the exposure, to someone who shouted at an arm's length away, and ears ring during or after the exposure (Dalebout, 2008). Even in well-designed system in the field of sound processing, noise still exist from external environment. In the concept of signal processing, noise has two different senses. Firstly, the signals that interfere each signal to the other signal would consider noise. Secondly, noise contains different frequencies which can cause lack of harmonic structure (Think DSP: Digital Signal Processing in Python, 2016).

## The Basics of Signals

Signal is defined as a function that changes over time. Signals such as sound, noise, light, and heat are signals found in nature (Jaber A. A., 2014). It is something that gives information such as traffic signal, distress signal, or even the smoke created in early days was used to convey information can be called signal (Lee & Lyons, 2014). There are two types of signals, it can be analog or digital if it is discrete in nature. Whether analog or digital it is necessary to treat the signals to provide better replication of information from the source signal. Treating of data is called signal processing. The process of sampling analog signal at specific timing repetition is known as "Analog to Digital Conversion" or ADC. The conversion of analog signal into the form of digital signal has certain advantages in the field of communications in terms of better accuracy and reliability of data, fast in computing algorithm, and ease of compressing the signal without distorting the information of signal (Jaber, 2014). A good example of equally sampled spaced in digital format is in the form of .WAV file, commonly term as waveform or wave. It has originated from Microsoft Corporation and IBM as the standard audio format for most personal computers. This audio, format was derived from taking audio signals and transforming it into binary signals. This file extension is used in processing the sound for LABVIEW Naturally .WAV file is an audio format can accommodate 44.1 kHz which makes it audible from the range 20 Hz to 20 kHz which is the range of sound that the human ear can hear. This provides a decent audio file format in terms of its audio quality. Signal can be in the form of acoustic noises generated by boiler, hydraulic, pneumatic system, rotating motor, or even air impact wrenches that is used for tightening bolts and air compressor. These noises are non-stationary signals. Non-stationary signals are better analyzed using wavelet due to its good time resolution for high frequency signal, making it possible to analyze in time and frequency domain (Walker, 2008)

A signal can be categorized as stationary or non-stationary. It is stationary if the frequency or spectral content did not change over time. This means that the signal will not change the frequency content of a sinusoidal wave with time while non-stationary signals will change the frequency component over a period of time. For example, a multi-tone with several intervals of frequencies changes from the other interval. It can be analyzed given the scenario like, if the first interval is 10 Hz, then 20 Hz, and 100 Hz this behavior of signal can be described as a non-stationary signal due to the changes of frequency over a period of time (IIT Guwahati, 2017).

Non-stationary signal can be categorized as evolutionary signal and transient signals. Evolutionary signals also change over time containing time-varying harmonics, this signals are oscillatory in nature. A vibrating guitar or a swinging of pendulum from back and forth is considered evolutionary signals (National Instruments, 2017).

According to Swiss Federal Institute of Technology Lausanne that time varying in nature is the transient vibration which nature is hard to predict since it behaves in a short time event. A particular example of transient signals such as excavator's combustion engine, a transmission system from the gear of a helicopter, electric drill, leaking sound from pneumatic and hydraulic system, sound generated by grinder when a cutting steel or a metallic plate. These are machines which exhibit transitory in nature and it can be found mostly in an industrial machinery.

Apart from being transient in nature, signals can be identified as asymmetric, sharp and irregular in nature. The challenge in analyzing transitory signal is possible using Daubechies (Db) wavelet transform, such as Db02 wavelet since its waveform is also asymmetric, sharp and irregular. The signals can be used to correspond with different wavelet transform for denoising. Usually the family of wavelet contains dilated and translated functions. It can be observed that in comparison to sinusoidal waveform it has infinite length while wavelet has finite length (Alaa & Robert, 2014).

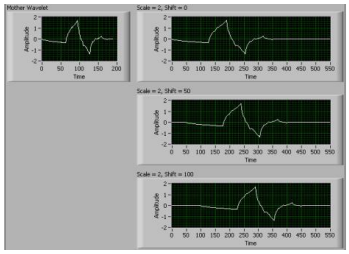



**Figure** Error! No text of specified style in document.**-1.** Image of Mother of Wavelet generated in LABVIEW (Source: National Instruments (2017))

The figures 2-2 shows how dilation and translation works for a mother of wavelet. The scale and shift of wavelet comprises to how mother of wavelet dilates and translates along x- axis (time-domain) a scale greater the one corresponds to stretch or expanding of wavelet along x-axis. Db02 is associated to the scale factor of 2 and so on, such as Db04 and Db08 with a scale factor of 4 and 8 respectively (National Instrument, 2016).

## Noise Reduction

According to World Health Organization (WHO) 2/3 of person's disability are accounted to hearing impairment of those people who are exposed to excessive surrounding noise. The Health Organization stated that as of March 2015, there are 360 million people worldwide have disabling hearing loss. With the given data about hearing loss, people realize that the noise reduction will be a great help to minimize the incidence of being deaf. Noise-canceling headphones come in either active or passive types. Manufacturers of headphone can provide passive noise reduction. This is due to the materials used in blocking out some external sound, Passive noise cancellation is effective at higher frequencies, but fails to remove sound at lower frequencies. A good noise cancelling headphone design, are built in circum-aural types which is specially modeled to attain noise-filtering properties, uses earmuff to avoid loud sound. Several designs were made to minimize the noise by incorporating materials with high sound absorption. A good design of passive cancelling headphone can eliminate sound level of about 15 to 20 decibels (dB). But for an aircraft engine, sound level can go up to 75 to 80 dB of noise. With this situation, passive noise cancellation will be ineffective. This is why the concept of active noise-canceling headphones plays an important role in reducing industrial noise. Active noise cancellation create sound waves that imitate the incoming sound to cancel out unwanted signals by producing soundwave that is 180 degress out of phase with the incoming sound. Different processes can be done to achieve noise cancellation (William, 2017). One of this methods is wavelet transform. Instead of producing soundwave which is the antiphase of the noise, wavelet provides different level of approximation and detail coefficients. This provides the information to examine which

coefficients produce noises, and from the known coefficients, noise can be removed using wavelet transform (Amit, Sharma, & Hegde, 2015)

## 3.0 EXPERIMENTAL SECTION

### 3.1 Materials

The materials for the experiments used are electric drill, laptop, and LabView Software 2014 version. The format of recorded sound is .wav file. A laptop is used as sound recorder.

### 2.2 Procedure

First, the recording of clear voice and electric drill noise signals were made separately. A combined voice and noise signals were also conducted. The wavelet coefficient for the voice and noise were obtained through wavelet transforms operation. The wavelet transform of the combined voice and noise were also produced.

Second, artificially synthesize combined voice and noise by merging the wavelet transforms of clear voice and the noise. Last, the resultant combined were clear voice and noise synthesized by inverse wavelet transform.

An algorithm was concocted to extract the voice from the synthesized combined clear voice and noise. The algorithm processed the wavelet transform of combined clear voice and noise. It made use of clear voice DWT as reference. The processed signal was transformed inversely and it was expected to recover the original clear voice. A number of experiments were made on db02, db04 and db08. It was expected that the clear voice could be extracted. For validation, the recorded combined voice and noise were used. The DWT was processed by the algorithm and the result was inverse-transformed. The processed signal was evaluated for clarity.

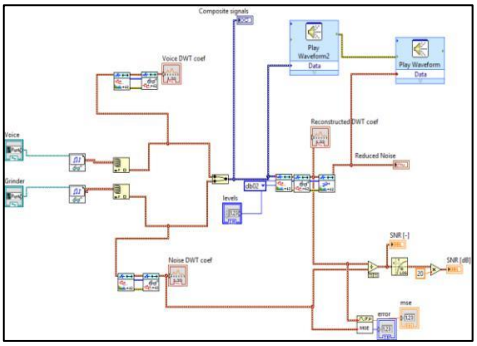



**Figure 1**. LABVIEW G-Code program for Active Noise Reduction using Wavelet Transform

**Table 1.** Sample Wavelet Coefficient of Voice Generated in Labview at specific level

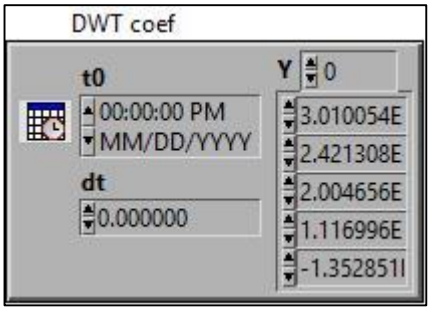



Table 1 provides information of sample wavelet coefficient which serves as the reference for subtracting the amount of noise in the composite signal.

## 4.0 RESULTS AND DISCUSSION

Below is sample result of the output waveform from different level of decomposition and daubechies wavelet transform. Figure 2 shows the combined Voice and Noise Signals.

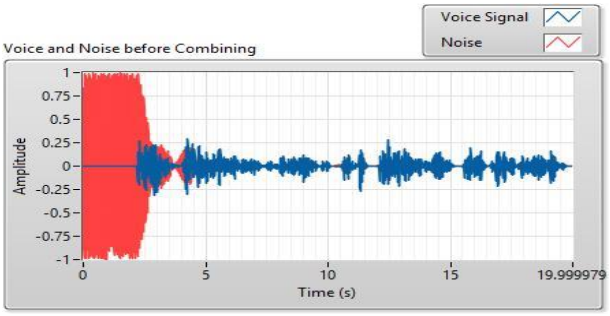
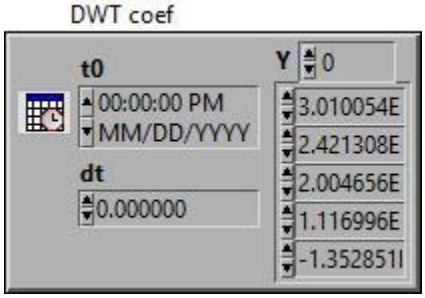



**Figure 2.** Unfiltered Voice and Noise Signal

Through a series of trial and error, the reference voice parameters were determined using the MRA LabView function. Out of db02, db04 and db08, db04 and db08 showed encouraging results.



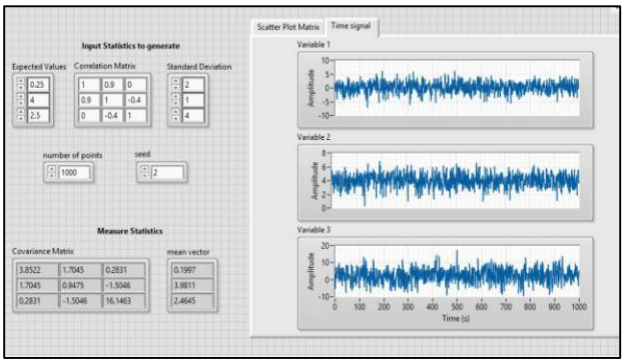



**Figure 3**. LabView function of reference voice parameters and Correlation of the three generated signals.

The extractions of clear voice were successful on db04 and db08. The db08 gave a much better results than db04. The sample of clear voice signal is shown in Figure 4. The changes in parameters were immediately reflected in the correlations results in Figure 3.

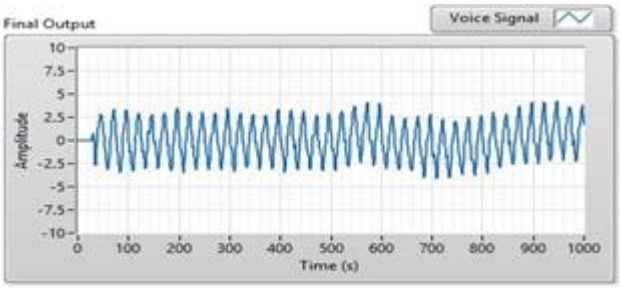



**Figure 4**. Voice as the reconstructed signal

The validation of algorithm using recorded combined voice and noise signal with similar results.

## 5.0 CONCLUSION

The effectiveness of reduced noise was validated using signal to noise ratio (SNR). The result shows that DB02 performs better from the combinations of voice-vacuum cleaner and voice-welding machine, while DB04 is better for voice-grinder combination. Lastly DB08 is better for voice –power drill combination and voice-single phase motor. This can be explained by the fact that Daubechies algorithm is adjusting to the waveform of different signals. This means that at lower level of Daubechies low frequency sound is better removed. Conversely, higher frequency sound is removed at higher Daubechies. Selection of appropriate level of decomposition for noise removal is necessary but care should be exercised since a higher level of decomposition may also destroy the quality of the voice signal.

The LabView G-Code program for Active Noise Reduction using Wavelet Transform can be used to design the hardware system for noise cancellation.

## 6.0 RECOMMENDATIONS

The next level of study would be the use of different noise sources as mentioned above. Different voices could be tested for noise cancellation using the developed algorithm.

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## 8.0 REFERENCES

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