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Research Article

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Industrial Acoustic Mitigation System for Real time Noise Cancellation

Chandana B R, Preethi P, Keerthi L Bangera* and Mohammad Abbubakar Fazil

Department of Electronics and Communication Engineering Sahyadri College of Engineering and Management (Autonomous) Mangalore, India

***Corresponding Author**
Keerthi L Bangera, Department of Electronics and Communication Engineering Sahyadri College of Engineering and Management (Autonomous) Mangalore, India.

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Abstract

High levels of noise are common in industrial settings, can act as a barrier to effective communication, cause loss of productivity, and in some cases be a safety hazard. Barriers and dampers are some of the typical passive control measure means. which however are unable to control low frequency sounds. The noise cancellation concept presented in this project employs active noise control principles through the use of an innovative industrial acoustic mitigation system ready for real time applications. The system uses microphones placed within the enclosing walls, process Digital signal processing (DSP) signals with a microcontroller and uses loudspeakers to produce anti-noise. Noise controlling active systems designs by embedded signal processing techniques has been the focus of interest of many designing and simulations. Among DSP methods, the system is capable of cancelling undesirable industrial noise over a given frequency range making the workplace healthier and safer by creative advanced selfish noise control techniques. The expertise of this technique is the real-time change and inexpensive module arrangement of materials which can be bought from the market easily. This project proposes a practical answer for those industries which are in need of efficient and flexible noise reduction techniques which also can easily be scaled. In conclusion, industrial practical operation noise control has advanced quite appreciably with the introduction and levels of use of this real time acoustic mitigation systems. Its applicability and effectiveness are useful in promoting health and safety in work settings where noise pollution is present.

Keywords: Active Noise Control, Real-Time Processing, Adaptive Filters, Industrial Noise Mitigation

1. Introduction

The main objective of the proposed system is to solve the problem of excessive noise produced by industrial machinery, which may affect worker health and lack communication in industrial settings. It's necessary for reducing noise levels in industrial settings since continuous exposure to excessive noise can lead to stress, hearing loss, and other health issues. Real-time noise level monitoring is provided by this technology, which enables prompt reaction to changing manufacturing noise levels. The system produces appropriate anti-noise signals that balance the harmful noise created by machines using cutting-edge active noise cancellation technology it successfully lowers sound levels by combining the noise and anti-noise, making the workplace safer and more peaceful for employees. This helps in increasing the productivity and communication between the employees in industrial environments and it reduces the risk of continuous exposure to noises and it provides safer work environment.

Here are some work the researchers worked on in order to reduce the noise with different modules:

The author mainly focused on developing a headset with active noise cancellation using a more advanced noise-cancelling algorithm [1]. In order to improve the audio quality and noise cancellation the Variable step size normalized least mean square (VSSNLMS) algorithm is used through feedback mechanism. When compared to other existing modules this headset's ability to remove unwanted noise was very effective. It reduced the noise by an average of 38dB, which was remarkably better than 14dBreduction from Least mean square (LMS) algorithm. Because of the new design the system could adapt and converge faster and the system became more flexible.

Li, Tao mainly focused on finding solutions for complex and unwanted noise issue in railway vehicles, which takes place due to number of sources [2]. The authors created a active noise cancellation system in order to address the issue by using a unique technology known as deep fuzzy neural network. The deep fuzzy neural network is used to create a virtual error signal which represents the optimal location for noise reduction. At first, they employed the convolutional network to calculate the noise signals coming from different sources in the railway vehicles. After this assumption they mainly focused on reducing the noise by using a fizzy neural network. Their method was tested using simulation, and the results showed that that it worked well, especially when it came to lowering low-frequency noise (below 1000 Hz).

Peng, An attempted to improve adaptive noise cancelling, it is a method that helps in removing unwanted noise from a signal [3]. They employed two different types of inputs i.e., the primary input, which had the signal mixed with noise and the reference input, which had noise associated with the primary noise. The original signal was adjusted by applying an adaptive filter to reference input [4]. They developed a mathematical model called wiener solutions to identify how well this method will work under different conditions, showing that it can remove noise without distorting the signal. They tested this technique in real world situation and found it to be very effective in several applications. For example, they used electrocardiography to remove interference from heart broad band noise [5]. They also found that this method could separate specific sounds, like sine waves, from background noise, which can be useful for improving sound quality in recordings and detecting weak signals hidden by noise.

There aren't many projects that specifically address noise cancellation in industrial environments and those modules that are already there in existence lack in real time operations. This project mainly focuses on active noise cancellation in industrial settings, the existing modules lacks in real time operation. Our goal is to develop a more efficient and responsive system that actively functions even in the loud environments in industrial settings by mainly focusing on both hardware advancements and software optimization [6]. The main effort is to make the current noise cancellation method faster and more effective in order for the system to function better in difficult situations, the main objective is to reduce the number of speakers and microphones, to more powerful and sensitive industrial grade models in addition to optimizing the software, which should improve the overall performance and make the system more reliable.

2. Methodology

Our project's main goal is to reduce the industry's noise pollution by using Digital Signal Processing (DSP). The microcontroller, gives robust processing ability and excellence in communication, it is the main component of our project. It makes it possible for us to collect and process data immediately. To control the noise input collected from high quality microphones placed in desired locations, we employ standard methods such as Least Mean Squares (LMS) and Finite Impulse Response (FIR) filtering. These methods, together with secondary path modelling, are vital for efficient suppression of noise [7]. The block diagram illustrates the overall function of our system. The method begins with an audio signal that contains unwanted noise. Superior microphones pick up this disturbing sound and send it to a processing unit for processing.

So as to neutralize the initial noise, we create anti-noise signals here.

First the sound that has been recorded is processed using adaptive algorithm that continuously monitors and reacts to the incoming noise levels. This shows that the system can adapt to changing noise levels in different environments, which is very important to its success. After processing, the signal is passed through a FIR filter, which catches only the required frequencies to achieve efficient noise reduction. This contributes to increased accuracy of the process. The signal is then inverted by using a device called signal inverter to generate the anti-noise.

Highest cancellation efficiency is achieved by properly adjusting each anti-noise output to accurately make up the source sound.

Sound-cancelling speakers use this new anti-noise signal to shut out unwelcome noise by emitting sound waves. Here, the concept of destructive interference is important; the initial sound waves and the anti-noise cancel each other out, producing greater clarity sound. One of the best things about our system is its ability to adjust in real time. Adaptive algorithms allow the system to adapt to changes in the noisy environment, ensuring that it continues to work well even when outside factors change. In summary, our unique method for noise cancellation not only solves present noise issues but also provides a long-term flexible solution that can change based on the noise level.

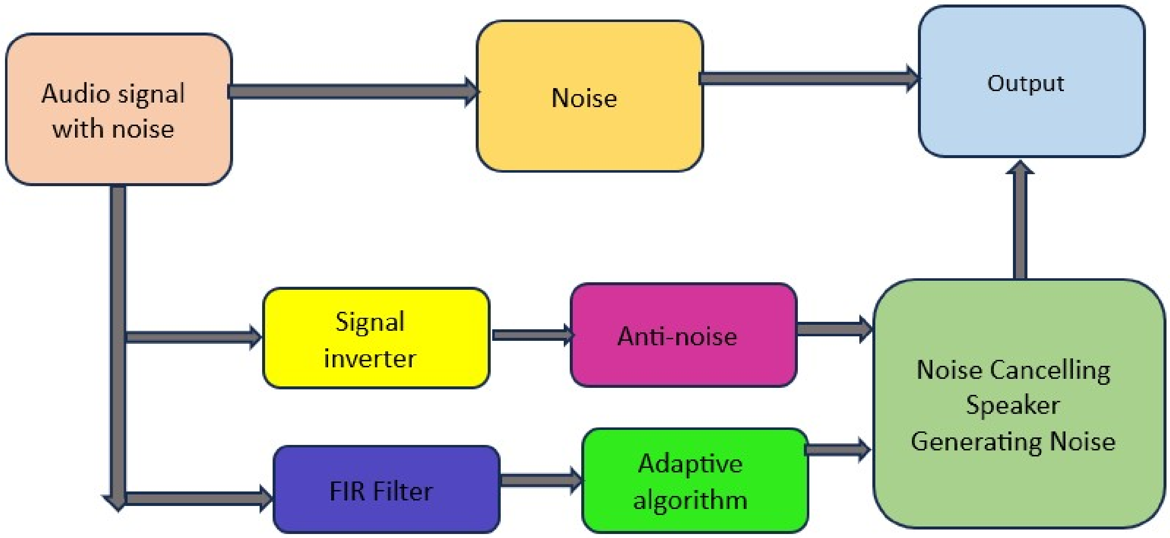

Figure 1: Block Diagram of ANC

2.1 Hardware Components

The microprocessor is the heart of the system which is responsible for controlling inputs and outputs as well as to run various noise cancelling algorithms. The microcontroller processes and analyzes the audio that the microphones capture using a fixed filter and adaptive algorithms by sending changed signals to the speakers, the device successfully lowers noise in factories [8]. Strong connection such as Bluetooth and Wi-Fi allow the microcontroller to deal with difficult sound processing tasks with ease. Its low power consumption is particularly crucial since it enables the system to function for a longer period of time, which is necessary in environments require continuous operation. The primary sensors in this module are microphones, that capture typical background noise.

For the noise reduction system to continue to work successfully over time, an uninterrupted power source is required. Because of this reliable electricity, every part including the speakers, microphones, and microcontroller can function without delay.

As a result, this modern noise reduction system creates a safer and more efficient working environment by combining modern technology with careful building.

2.2 Software Components

The main part of the noise cancellation technology is the DSP processor, which is needed to control and involve noise received by microphones. This method successfully reduces unwanted audio by creating an "anti-noise" output after the sounds have been filtered. One of its unique features is its real-time operation, which allows it to reduce noise almost quickly upon detection. This flexible technology is very useful in a range of areas since it can be configured to target specific frequencies. The program uses advanced methods like the Fast Fourier Transform (FFT) to analyze sound successfully.

As a result, even when levels of noise change, the system continues to function quite well. A microcontroller continually improves the anti-noise signals by using data in real time [9,10]. the Finite impulse response (FIR) filter is required to this method since it reduces unwanted noise frequencies. The filter's design controls and identifies what type of noise and it will identify reject. The software that connects to the FIR filter allows the user to vary the filtering procedure by modifying the settings, users can target various noise frequencies that are typical in their industrial setting.

A easier user interface of the noise cancelling system allows the users to change settings, measure performance and check noise levels in real time. The FIR filter operates in real time operation. The system utilizes least mean square (LMS) algorithm created in MATLAB to adapt to changes in noise characteristics. This flexibility is essential to guarantee the system's durability.

Parameter	Description	Value
Filter Type	FIR	Adaptive
Sampling rate	Frequency at which signals are sampled	44.1kHz
Filter Length	Number of taps	128
Cutoff frequency	Frequency below which noise is targeted	200Hz
Target noise type	Industrial machine noise	Low frequency, continuous
Noise source	Source of unwanted sound	Machinery
Expected reduction	Estimated noise reduction range	10-15dB

MATLAB algorithm	Adaptive LMS	Dynamic adjustment
Input signal source	Microphone array	Directional microphone
Output signal	Anti-noise signal emitted	Speaker array

Table 1: Fir Parameters

3. Result & Discussion

The LMS algorithm's application of ANC shows a noticeable improvement in removing unwanted noise in industrial environment. It mainly uses a process that includes recording of noise signal and processing them using LMS algorithm by producing anti-noise signal, the system actively reduces the effects of background noise. This implementation shows a number of important outcomes. First, the LMS algorithm's adaptive filtering features allows the system to react continuously to the variation of noise levels and properties, in industrial settings noise patterns might vary significantly as a result of shifting machinery or environmental factors this flexibility is crucial [11,12]. The LMS algorithm's application of ANC displays remarkable improvements in removing unwanted noise in industrial environments. It uses a process that includes recording noise signals and processing them using the LMS algorithm by producing anti-noise signals, the system reduces the effects of background noise on the workers and equipment. This implantation result shows a number of important outcomes. First, the LMS algorithm's adaptive filtering features allows the system to react continuously to changing noise levels and properties, in industrial settings noise patterns might alter significantly as a result of shifting machinery actively or environmental factors, this flexibility is essential. There is a noticeable reduction in background noise as the system's anti-noise signals successfully cancel it out. According to noise reduction measures, the ANC system can actively lower decibel levels in specific locations, in real world application 10-29 dB reductions have been noted, by greatly enhancing the working environment for employees. This decrease not only improves comfort but also helps workers focus and be more productive because they can work with less noise to distract them. Additionally, user qualitative response has been overwhelmingly good. Employees have expressed satisfaction with their working conditions, describing a calmer and less demanding atmosphere. This improvement is especially crucial in fields where loud noises can cause long-term hearing impairment, weariness, and lower productivity. Robust analysis and visualization of the LMS method have been made easier by the use of MATLAB.

Parameter	Frequency [HZ]	Noise Level [Amplitude]
Original Noise	200Hz	1x10^4
Anti-Noise	200Hz	1x10^-10
Output	Negligible	Close to 0

Table 2: Table Regarding Noise Levels of Noise and Reduced Noise

The table 2 shows the frequency and noise levels in different stages of the process that can effectively enhance the environment. A common low-frequency range that is created by industrial machinery, such as motors and engines, is 200 Hz, which is the frequency used for both the original noise and the anti-noise signals. Because reducing this particular frequency can effectively enhance the environment. The original noise, collected at 200 Hz, has a large amplitude (1x10^4). This suggests that there is a loud, continuous noise present, which is common in industrial environments. In order to prevent this, the system produces an antinoise signal that is opposite in phase and has a frequency of 200 Hz, matching the original noise and allowing destructive interference. The very low amplitude of this anti-noise signal (1x10^-10) is enough to cancel out the original noise without adding more sound. This procedure effectively shows the FIR filter's capacity to remove unwanted noise by causing the output noise level to drop nearly to zero. In order to make sure that the system functions efficiently and creates a more controlled and quite environment in industrial areas, this parameter setup is essential.

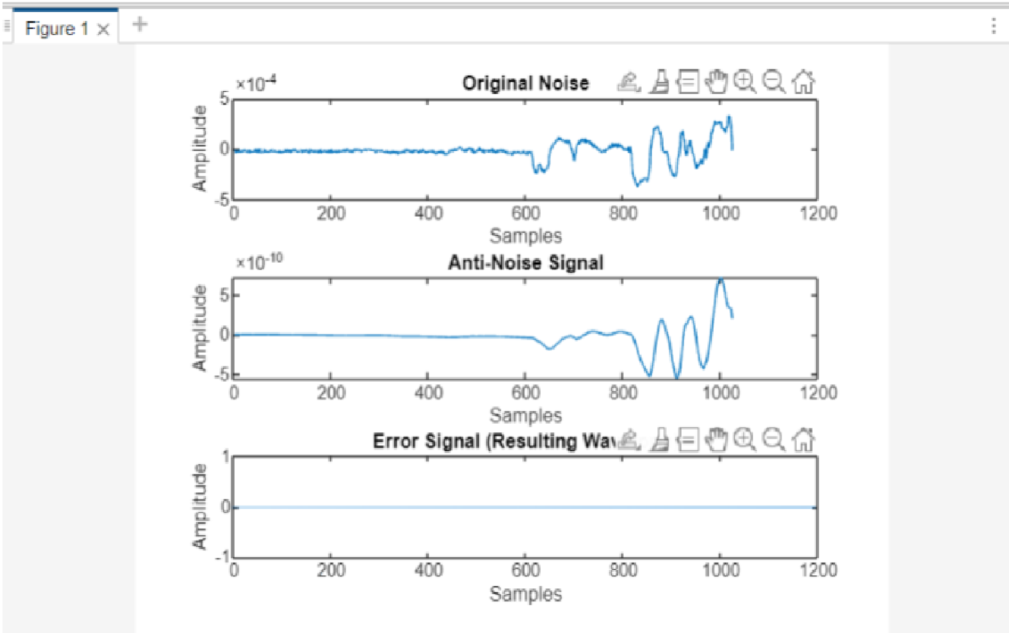

Figure 2

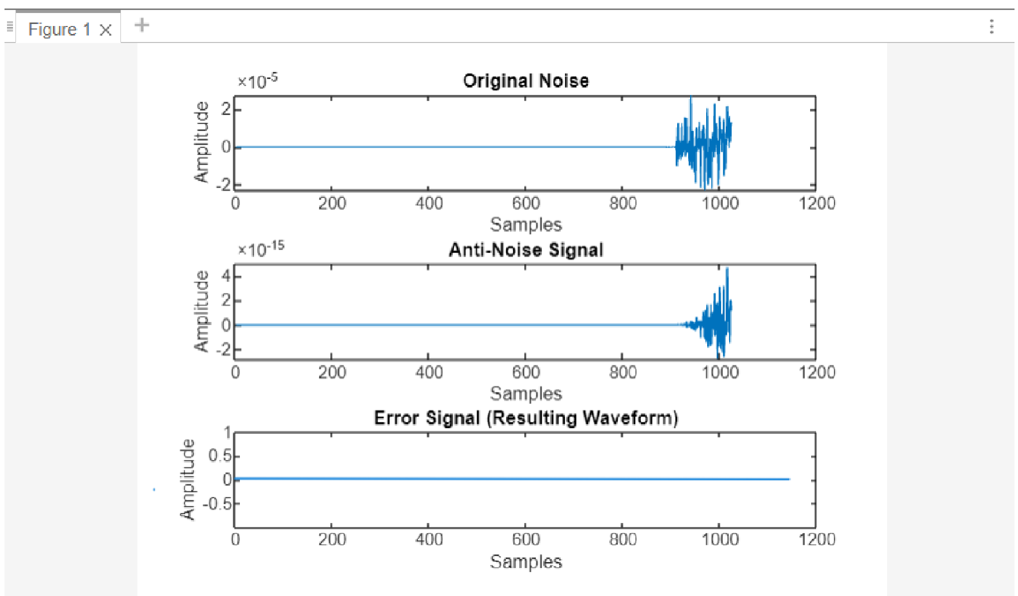

Figure 3: Output for ANC Using MATLAB

Fig 1 shows a setup with the MATLAB code and graph of an active noise cancellation system. The code sets up the parameters like sampling frequency, filter coefficients, and the duration for which the noise is monitored. The process mainly involves actively monitoring an original noise signal and generating an anti-noise signal in the middle, and the output after noise cancellation at the bottom, This main goal is to show how effectively the anti-noise signal reduces the amplitude of the original signal resulting in reduction of the noise.

Fig 2 shows a similar setup with the MATLAB code. The graphs compare the original noise, which remains same, the anti-noise signal is generated to cancel it out. The final graph displays the outcome of this cancellation. This indicates that the active noise control system effectively reduces the original noise, by achieving the expected outcome of noise reduction.

4. Conclusion

The Industrial Acoustic Mitigation System actively monitors and reduces excessive noise in industrial environment by using real-time noise cancellation. The system creates anti-noise signals to eliminate the original sound after monitoring unwanted noise and processing it using advanced DSP algorithms in MATLAB. The initially generated noise in this case has a frequency of 200 Hz and an amplitude of 1×10^4. Because the system produces an anti-noise signal with the same frequency (200 Hz) but much smaller amplitude (1×10^{-10}), the output noise level is very low. The above graphical representation shows the system's performance. The top plot shows the initial noise signal with a noticeable amplitude. The middle plot shows the phase-inverted anti-noise signal, which is meant to remove the original noise. The bottom plot shows the output signal. It constantly remains close to zero, showing that the noise cancellation procedure is successful. Compared to other noise reduction methods that require costly soundproofing or physical barriers, this device is highly adaptable and can be readily integrated into existing machinery designs without affecting the operations. It can respond to changing noise patterns and keep working effectively in any industrial setting due to its real-time adaptability. This technology also increases worker comfort and safety by reducing the health concerns related to noise and boosting productivity. It is a sustainable and environmentally friendly option for current industries since it reduces industrial noise pollution and improves adherence to environmental laws.

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