Solution for Vehicles Noise Cancellation With Modification of LMS Adaptive Algorithm

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Abstract **--- The problems of noise cancelling systems are based on the specific characteristics of their sources. Therefore, the knowledge of each noise source should be represented prior to the excecution of the designed noise cancelling scheme. Since the noises emitted vary with the types of the passing vehicles, the scheme should be well adjusted automatically. The delay must be minimixed by managing the value of step size.**

Five representing types of noise producing vehicles (noise from: bus, truck, motocycle, car with diesel fuel, and car with gasoline) were always changing following the passing vehicle. The robust LMS (*Least Mean Square*) algorithm was applied first, then followed by modification LMS algorithm.

The results show that LMS algorithm with two process, which is modification from adaptive LMS algorithm is the simplest and the best if it is applied in vehicle's noise cancellation.

Key words: ***LMS (Least Mean Square), delay, step size, filter length.***

I. Introduction

Many jobs needs more concentration in order to get an optimal result. In many big cities, noise occur from transportation activity, factory machine, building construction, road construction and many more. Many effort have been done to reduce noise pollution, but not all noise pollution can be reduced, or in other words, noise can not be eliminated 100%. This is because of the noise style always changes quickly.

One of the way to eliminate noise pollution is building noiseproof room with noise absorber or noiseproof material. This way is very good for computer laboratorium, court room, etc. However, not all building is suitable with this noise-proof system. This is because of the cost factor and there is certain noise that should be heard. This condition can be seen in housing complex, schools, and offices which are located near main street. These facilities need noise control equipment effectively and selectively.

The vehicle's noise usually contains static pattern, in other words repeated periodically or random stationary in a long period of time. The noise in static pattern sounds disturbing, nevertheless in aloud noise and continuously.

One of the way to reduce noise pollution is making a noise cancellation system that still can maintain information signal which is called "*tutur*". Because of many types of vehicles, the adaptive ellimination process should be used in order to follow the type of noise.

1.1 Destination

The destinations of the research are:

1. To observe many stationair noise signals come from vehicle's noise signals. It means to meet the basic characteristics of the vehicle's noise signals spectrally and statistically.
2. To take the best algorithm for vehicle's noise cancellation based on LMS adaptive algorithm.

1.2 Contributions

From the various vehicle's noise and many adaptation scheme, it is expected can open the opportunity for making the complete hardware and software for stand alone and real time adaptive noise cancellation. Beside, it can make scientists develop the same adaptive methods and technics for another noise

II. Basic Theory

The parameter of the adaptive systems depend on the value of input and output. So, the adaptive algorithm process the system and then the result must be close to the desired. The system depends on its scheme. Figure 2.1 shows the adaptive system which has the core of adaptive process.

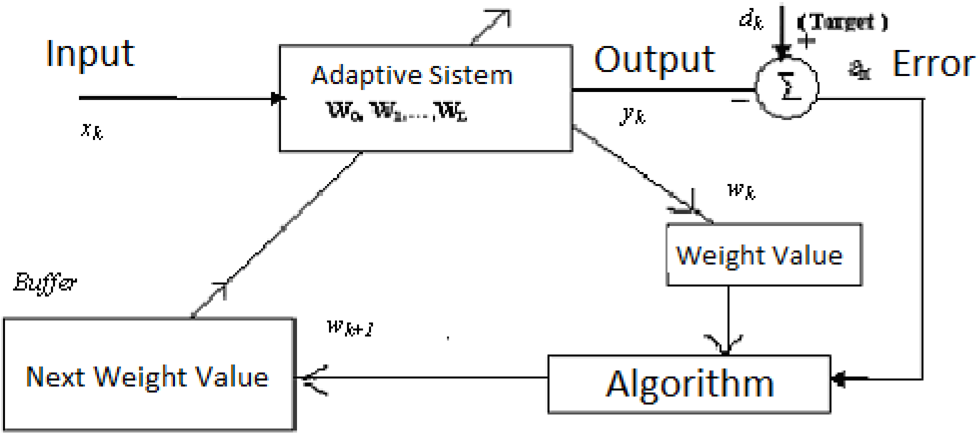


Figure 2.1 Commom adaptive systems scheme

If the the common adaptive system added with some block or subsytems, then it will become some modificated configuration. The best configuration for vehicle's noise cancellation is the configuration with two input. The first input contains s_k and noise n_k, the second ones contains only noise n'_k. The noise n'_k and n_k come from the same source, but they were recorded from the different place. Figure 2.2 shows the configuration of noise cancellation with two input.

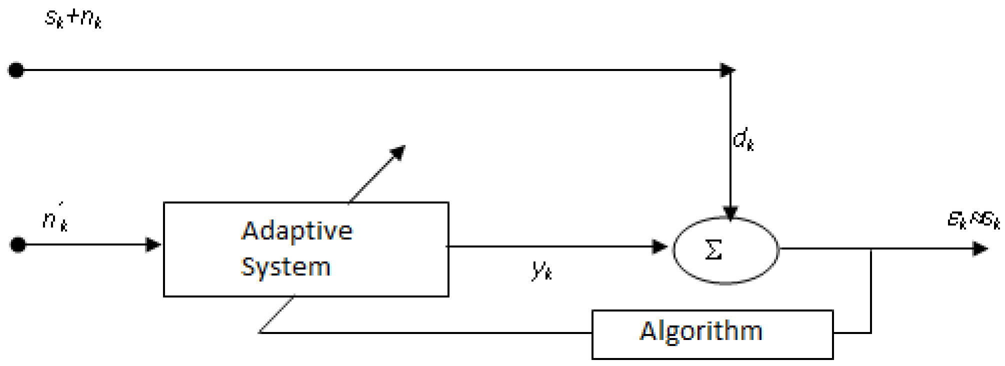


Figure 2.2 Configurration of noise cancellation with two input

Adaptation was expected working in a stasioner signal condition that have constant mean, varians, skewness, curtosis, and correlation function, or can be simplied as a WSS (Wide Sense Stationary) that only need constant mean and variance. So the algorithm must be fit with that conditions in order to have correct adaptation. The LMS (Least Mean Square) algorithm to be presented as a main reference. Although have a long iteration, LMS adaptive algorithm have a simply computation.

Analytical of Adaptive LMS Process

Many usefull adaptive processes that cause the weight vector can seek the minimum value of the performance surface done by gradient methods. The gradient of the mean-square-error performance surface, designated $\nabla(\xi)$ or simplied ∇, can be obtained from

$$\xi = E[\varepsilon_k^{\ 2}] = E[d_k^{\ 2}] + \mathbf{W}^{\mathrm{T}}\mathbf{R}\mathbf{W} - 2\mathbf{P}^{\mathrm{T}}\mathbf{W} \qquad (2.1)$$

differentiating to obtain the column vector

$$\nabla\xi = \frac{\partial\xi}{\partial W} \quad \begin{bmatrix} \nabla_0\xi \\ \nabla_1\xi \\ \vdots \\ \nabla_L\xi \end{bmatrix} = \begin{bmatrix} \partial\xi/\partial w_0 \\ \partial\xi/\partial w_1 \\ \vdots \\ \partial\xi/\partial w_2 \end{bmatrix}$$

for R = E[$\mathbf{X}_k\mathbf{X}_k^{\mathrm{T}}$] and P = E[$d_k\mathbf{X}_k$] then

$$\nabla\xi = 2\mathbf{R}\mathbf{W} - 2\mathbf{P} \qquad (2.2)$$

Assuming that R is nonsingular, the optimal weight vector W*, sometimes called the Wiener weight vector become

$$\mathbf{W}^* = \mathbf{R}^{-1}\mathbf{P} \qquad (2.3)$$

The meaning of that equation that the weight's values will be greater if there is strong cross-correlation between x_k and d_k and will be smaller if there is a weak auto-correlation of x_k.
Figure (2.3) shows the condition of the steps of adaptation, the weight value changes porpotional with the gradient value.

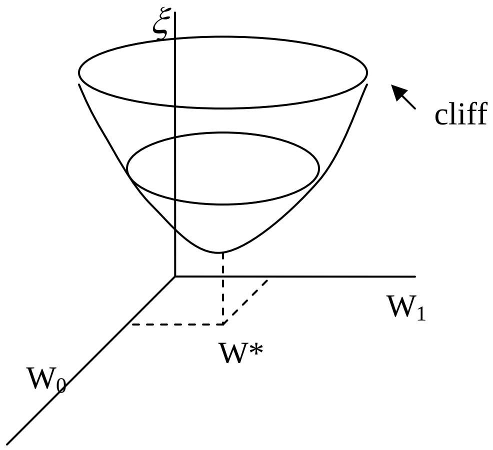


Figure 2.3 Performance surface

Because of **W*** =**R**$^{-1}$**P,** it could generelize Newton's method

$$\mathbf{W}_{k+1} = \mathbf{W}_k - \mu\mathbf{R}^{-1}\nabla\xi_k \qquad (2.4)$$

In the case x_k and d_k was unknown , R can't be used in the algorithm, so the algorithm become Steepest Descent algorithm

$$\mathbf{W_{k+1}} = \mathbf{W_k} - \mu \nabla_\mathbf{k} \quad (2.5)$$

LMS algorithm was formed from partial derivative of $\varepsilon_k{}^2$, with the assumption that mean of $\varepsilon_k{}^2$ reach the minimal value. The LMS algorithm is

$$\mathbf{W_{k+1}} = \mathbf{W_k} + 2\mu \mathbf{X}_k \ \varepsilon_k \quad (2.6)$$

The simply LMS algorithm take long time for reaching the optimum value.

III. Research Methods

This research realizes the adaptive noise cancelling system that has two inputs. The two inputs must take without delay time. The noise recorded from five vehicles, there are diesel's vehicle, car, motorcycle, bus, and truck. The first input recorded in the work room and the second input recorded near the noise source. The aim of the research is cancelling the noises without losing the information.

This research took cross-correlation and auto-correlation to fine any resemblance between vehicle's engine noises such as from cars, buses, trucks, motor cycles, and diesel powered vehicles, compared to those of human speech signals. Correlation took the important process, because of the formula $\mathbf{W}^* = \mathbf{R}^{-1}\mathbf{P}$. Fitting curve of the result of auto-correlation and also cross-correlation can help simply the correlation signal.

Analysis FFT and spectrum for vehicle's noise can show the location of the frequency of the noise. it is expected that the frequency of the noise different from the information. On the contrary, the frequency of the noise from inside the work room close to the noise from the outside ones. For optimizing that the research could be done, it's compared with the sine signal, because the sine signal was the periodic and easy to cancell.

The important case in this research is looking for the optimal value of the three variable, L (filter length), μ (step size), and delay time. Before seeking the optimal value for vehicle's signal, it's observed the optimal value for sine, sawtooth, etc.

The research do untill the noise could be cancelled, but still leaving over the information. The difficulty is frequency of the noise and information signals have the same range. That condition cause the modification of the algorithm.

IV. Result and Conclusion

4.1 Correlation

This research realizes the adaptive noise cancelling system that has two inputs. The first input is information signal with vehicle's noise and the second ones is the vehicle's noise itself as a reference. The noise recorded from five vehicles, there are diesel's vehicle, car, motorcycle, bus, and truck. The first input recorded in the work room and the second input recorded near the noise source. The aim of the research is cancelling the noises without losing the information.

From the research before, some researchers only use the synthetic signal. Even, some of them only analize the stochastic of the certain algorithm. The research which take original signal from the real condition like this research was not done yet, especially in Indonesia.

Beginning with the correlations, which are the conditional of the successful of the noise cancellation with LMS algorithm, then take the auto-correlations of several vehicle's noise signals, from cars, buses, trucks, motor cycles, and diesel engine powered vehicles, then compare them with those from speech signals.
Figure 4.1 shows the Scatter plot of the first two coefficients of the respective fitted curves of cross-correlation vehicle's noise signals.

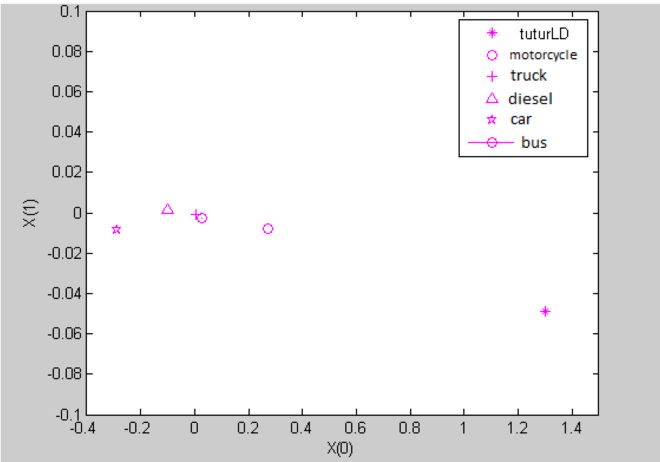


Figure 4.1: Scatter plot of the first two coefficients of the respective fitted curves of cross-correlation vehicle's noise signals.

Figures 4.1 shows clearly the spread of the correlation coefficient values with some degrees of clusterings of those of similar vehicle's types, while at the far end is that of speech signal. This suggest a good chence for separating speech signal from the noise.

Figure 4.2 shows the cross-correlation of the vehicle's noise signal with and without speech signal. It could be concluded that there is no significant differences between cross-correlation of the vehicle's noise signal with and without speech signal.

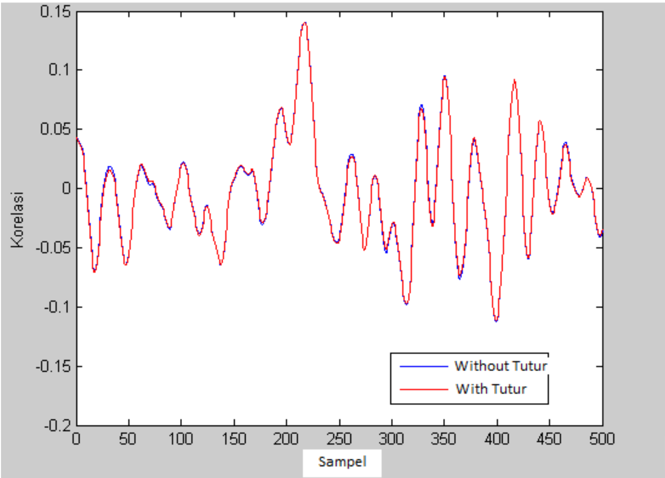


Figure 4.2 The cross-correlation of the vehicle's noise signal with and without speech signal.

4.2 FFT Analysis

The FFT analysis of the vehicle's noise signals show the complex value of the FFT result was not like circle perfectly. On the contrary, the sine signal has the complex value as a circle. It means harmonic periodic, so the sine signal easy to cancell. And there is an random vehicle's error residu that can't cancell anymore. Figure 4.3 and 4.4 show the real and imaginair value for bus signal, and the real and imaginair value for sine signal.

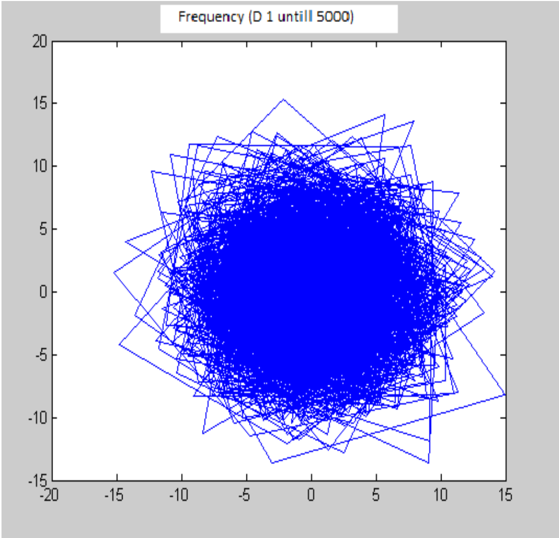


Figure 4.3 Real and imaginair value for bus signal from inside the workroom(1 – 5.000).

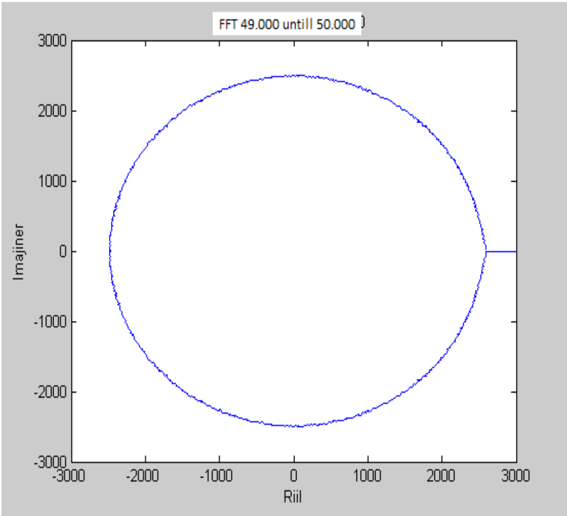


Figure 4.4 Real and imaginair value for sine signal (49.000 – 50.000).

4.3 Analysis Spectra for Vehicle's Noise

Almost all of vehicle's noise signal show that they are in the low frequency while infomation or speech signals are in the low and high frequency. This condition open the opportunity that the noise signal could be cancelled from the speech signals. Figure 4.5 shows the spectrum of vehicle's noise and figure 4.6 shows the spectrum of speech signals.

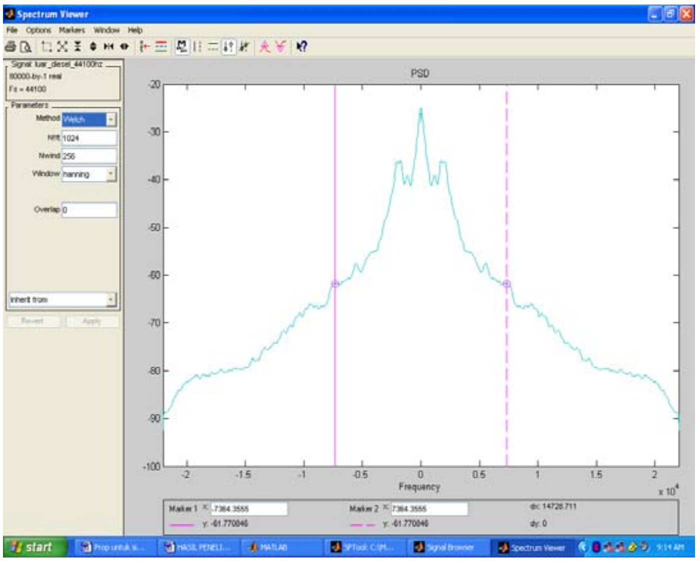


Figure 4.5 Spectrum of vehicle’s noise signal from out of workroom with the sample frequency 44100 Hz

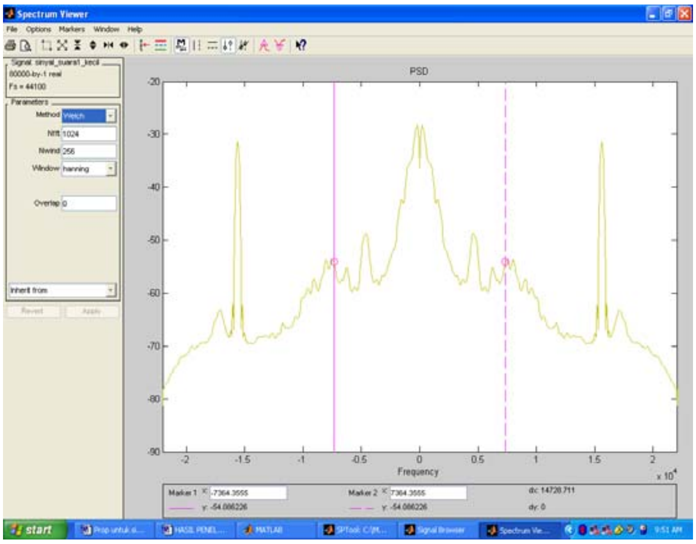


Figure 4.6 Spectrum of speech signal with the sample frequency 44100 Hz

Correlation, FFT, and spectra analysis show that the speech signal could be disjoined from the vehicle’s noise. So, with that confidence of that success, this research will be continued with looking for the correct parameter’s value that used for LMS algorithm.

The research looking for the parameter’s value beginning with the simply signal, there are sine, sawtooth, and square signal. In the reality, sine signal can cancell qiuckly and perfectly by LMS algorithm, but the vehicle’s signal more difficult to be cacelled because the adaptive process meet difficulties in finding the correct step value μ .

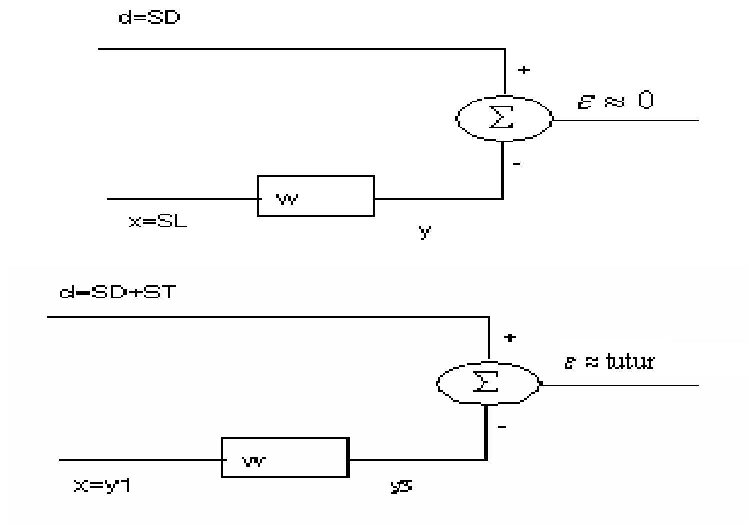
4.4 Finding μ and L in Adaptif LMS FIR Predictive

This Adaptif LMS predictive for vehicle’s noise signal was done with the desired input equals to the reference. The result must be show that the error close to zero, for all k iteration. But, in the reality the error ε close to the fix interval and oscilate in that interval. It because the error ε still have computation error, and the statistic and correlations show that the error residu close to white Gaussian noise.

4.5 Apply LMS Adaptive on The Vehicle’s Noise

To finding of the μ , L, and the correct delay sample, the non predictive LMS adaptive for vehicle’s noise signals was done complicatedly. There are many way to find the μ , L, and the correct delay sample, there are overlap and not moving average, MSE, maximum weight for some delay sample. From that research, it can be found that μ =0,001, L=150, and the correct delay sample is 200. But, that result still have bothering noise. So, the noise cancellation does not success yet.

Finally, with the long research, made the modification of the LMS adaptive algorithm, that is LMS adaptive algorithm with two process (Figure 4.7). The first process, the desired input is the vehicle's noise that recorded inside the room, and the reference is the vehicle's noise that recorded outside the room. In the second process, the desired input is the sum of the desired and the reference of the first process. The reference of the second process is the output of the first process.



Gambar 4.7 LMS adaptive with two process

In finding the optimum value, LMS adaptive process with two process use MSE as a reference. The step size of all vehicle's noise in LMS adaptive with two process have the same value, that is 0,001. And the L and delay optimum are 230 and 100 samples.

The conclusion from the above is the adaptive LMS algorithm with two process, which is modification from adaptive LMS algorithm is the simplest and the best if it is applied in vehicle's noise cancellation.

Cosidering that the adaptive LMS noise cance

llation become more perfect if all noise signals is filtered low pass before, so with the appropriate hardware can be choosen the optimum L (if it is possible, the value of L can be used bigger than 470) so that the vehicle's noise cancellation be performed well. Besides twith Matlab program the time which is needed to cancell the vehicle's noise signal in 80000 samples is 91.091.000 seconds or it's around 15 minutes. It can be seen clearly if we know the weight value of vehicle's noise signal, the time we need to cancell the noise is shorter. In the above process we can save time untill 13,5 minutes or 90%. We can make a conclusion from the fact above with appropriate hard ware and know the weight value of each vehicle's noise signal, adaptive noise cancellation could be realized in real time.

4.6 Conclusion

The result of the researh from the above explanation, can be concluded:

1. The analization about correlation, FFT, and spectra suggest a good chance for separating speech signal from the noise although there are many difficulties for finding the appropriate delay, filter length, and step size.

2. Noise cacellation which comes from various type of vehicle's noise can be done with the adaptive LMS algorithm, This algorithm has been modified in two process level with L = 230, μ = 0,001, and delay 100 samples with the simplest structure in linear combiner.

VI. REFERENCES

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