Computer Engineering and Applications Vol. 7, No. 3, October 2018

Characterization of the Dolphin Ultrasonic Waves Using Wavelet Transform for Autism Therapy

Herlinawati, Umi Murdika, FX Arinto Setyawan

Department of Electrical Engineering, Faculty of Engineering, Universitas Lampung
fx.arinto@eng.unila.ac.id

ABSTRACT

Autism is a neurobiological development disorder experienced by a person from birth or toddlers. Autistic sufferers have difficulty in forming social interaction, communicating, emotional, sensory and motor disturbances as well as slow or abnormal mental development. Therefore, people with autism will be isolated from normal human beings and enter the world of repetitive, activities and obsessive interests. Autism therapy using dolphins that produce ultrasonic waves with a certain frequency can align the function of motor and sensory nerves of patients with autistic. A direct therapy using dolphins requires a special time and a cost is quite expensive for once therapy. This research proposes autism therapy with artificial dolphin ultrasonic waves based on signal characterization issued by dolphins. The main difficulty in this characterization is to eliminate the unwanted signals (noise) from the desired signal when recording the signal issued by the dolphins. Noise filtering (denoising) is done using wavelet transform. This research proposes a model of a dolphin ultrasonic wave characterization using wavelet transformation by determining decomposition and threshold levels to obtain the best signal quality for autism therapy. The effectiveness of the proposed method is measured using the SNR parameter. The results showed that the level of decomposition 5 and hard threshold gave the highest SNR value compared to the others.

Keywords: Autism, Denoising, Noise filtering, Wavelet, Decomposition

1. INTRODUCTION

Autism is a developmental disorder of the nervous system that affects a person in communicating, socially interacting, and behaving. Autism is mostly caused by heredity factors. Sometimes this disorder has been detected in infancy or 6 months of age. There is no way to cure autism with certainty, but treatment as early as possible with appropriate therapy and treatment of autism will result in autism in children can be controlled. If not, then the longer the patient will be more left behind with a child his age and can continue until adulthood.

Many types of therapies can be done to reduce this disorder. Previous research on autism therapy has been widely practiced. One of the previous researches conducted by Simpson is using music to overcome nervous system disorders [1]. The study involved 20 children with autism. The results prove that people with autism prefer to be involved in conditions sung compared to oral conditions.

Another study conducted by Fithri using a religious approach to overcome the disorder of autism [2]. According to this research after being given religious therapy, the children are easier at controlling their emotions and calmer. The research involved 12 autistic children in Taruna Al-Qur'an special school. The disadvantage of this study is to use only one type of a religion and have not done the research for the other religions.

The uses of animals to aid autism therapy also have been the object of research. Many animals are used for help autism therapy, for example Horses, dogs, guinea pigs, and Dolphin [3]. Research on autism therapy specifically using horses and dogs is done by Seiwertsen [4] while specifically using marmots performed by Krskova [5]. The use of these animals provides a positive effect for people with autism on their social behavior.

Another animal widely used in autism therapy is Dolphin [6][7]. The results of this research indicate that an ultrasound emitted by dolphins with enough intensity, repeated for several days or weeks with a certain duration can be affected the biological tissue. The research results showed a significant decrease in stereotypical behavior, significantly increased communication and social interaction of autism sufferers. The disadvantages of this method are the high cost of therapy and limited therapy time.

Research about a signal characterization using wavelets has also been widely used. Reaz uses wavelets for characterizing EEG signals for people with disabilities [8]. The characterization results are applied to the FPGA to create intelligent wheelchairs for people with disabilities. The result of this research proves that wavelets provide a better noise filtering results, such as notch filter and filtering methods in the frequency domain. Research about the characterization of ultrasonic signals using wavelets has also been done [9]. This research successfully derived a spectrotemporal representation of a typical ultrasonic pulse.

The proposed method in this research prioritizes the characterization of ultrasonic waves generated by the dolphin in order to be replicated. The goal is that the cost of therapy is more efficient and can be done anytime. The proposed method is the signal characterizations using the wavelet transform to be applied to the resulting of recording dolphin-generated signal.

2. LITERATURE REVIEW

Noise is an unwanted signal that appears during transmission and may cause the original signal to become damaged or disconnected. Noise can occur when recording or retrieving a signal. The value/number of noise cannot be determined precisely, but can only be formulated in its approximate value or range of values. The received signals can be formulated with the following equations:

$$f'(x) = f(x) + n(x) \tag{1}$$

Where $f'(x)$ is the signal received by the receiver, $f(x)$ is the original signal, and $n(x)$ is noise.

Ultrasound waves are high-frequency sound waves above the human hearing range, which is above 20 kHz. Therefore, humans are unable to hear this ultrasound sound. There are some animals that can make this high-frequency sound. The

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

Dolphins are using it to communicate with each other, while the bats use it for navigation.

The ultrasound waves produced by dolphins can be used for autism therapy. This therapy is quite expensive because it must interact directly with the dolphins and limited therapy time. Therefore, it is necessary to characterize the ultrasound frequencies produced by the dolphins by separating them from the noise that arises during the recording. At the time of recording, the recorded sound is not only the sound of the dolphins, but there are disturbances that may arise during the recording. Disturbance can be the sound of moving water or the sound of other objects that are not desired.

2.1 DENOISING

Denoising is the process of extraction of signals from the original signal mix with noise or a noise removal process so that the receiver gets the real signal. Wavelets could be used for this denoising process [8]. The wavelets transform to reduce noise assumes that time series analysis at different resolutions could be separated between the original signal form and its noise.

Denoising procedure consists of 3 steps: decomposition, detail threshold coefficient, and reconstruction. In this study, signal decomposition is tested up to 5 levels to see which one is best while for the threshold is tested for soft and hard threshold types.

2.2 WAVELET DECOMPOSITION

Wavelet decomposition is a process whereby the signal is separated into two parts with the same number of samples. The separation process is carried out by entering the signal into a system that has two types of filters: low pass filter (g [n]) and high pass (h [n]) with identical cutoff points. The process is continued by modifying the signal based on the scale and time function. This process is performed repeatedly to determine the discrete wavelet transform level. This process will affect the magnitude of the frequency band in each coefficient. Figure 1 shows the wavelet decomposition process.

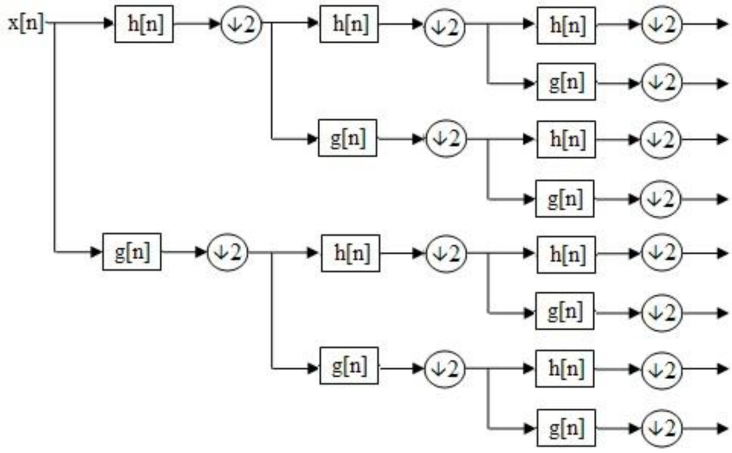

FIGURE 1. Ilustration of the wavelet decomposition

This decomposition process can be done through one or more levels. The one-level decomposition can be expressed mathematically using the equation:

$$YHigh[k] = \sum_n X[n]h[2k - n] \quad (2)$$

$$YLow[k] = \sum_n X[n]g[2k - n] \quad (3)$$

Where *YHigh* and *YLow* are the result of high pass and low pass filters, *x[n]* is the original signal, *h[n]* is a highpass filter and *g[n]* is a lowpass filter.

In the Haar wavelet, the wavelet coefficients and the average set are always taken into account in each step of the transformation. Mathematically, a wavelet coefficient (c_i) and an average set (a_i) can be calculated using the equation:

$$c_i = \frac{s_i - s_{i+1}}{2} \quad (4)$$

$$a_i = \frac{s_i + s_{i+1}}{2} \quad (5)$$

where s_i is the i-th data, s_{i+1} is the data after i-th data, s_{i-1} is the data before i-th data, *a* is the data average, and *c* is the wavelet coefficient.

2.3 THRESHOLDING

Many methods were introduced to set the threshold. This research uses two thresholding modification methods, namely hard threshold and soft threshold. In this research, each thresholding method was tested on the decomposition level 1 to 5.

In the hard threshold method, the coefficients that are below the threshold those are affected in value and replaced by zero while the other values not change. The hard threshold can be expressed mathematically by the equation:

$$\partial_\lambda H(x) = \begin{cases} X & |X| > \lambda \\ 0 & X\ another \end{cases} \quad (6)$$

Where λ is the specified threshold value. In this method, the X value above the threshold is untouched.

Unlike the hard threshold, on the soft threshold, all coefficients undergo a modification process. The coefficient having of absolute value above the threshold value will decrease while the other coefficient is made zero. The soft threshold can be expressed mathematically by the equation:

$$\partial_\lambda S(x) = \begin{cases} x - \llcorner & x > \lambda \\ 0 & x \geq \llcorner \\ x + \llcorner & x < -\lambda \end{cases} \quad (7)$$

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

2.4 MEASUREMENT OF METHOD EFFECTIVENESS

The effectiveness of the proposed method is measured using the Signal to Noise Ratio (SNR) parameter. SNR is a comparison between the original signal and its noise. The greater the SNR value indicates that the original signal is greater than its noise value. Therefore, SNR is used to determine the character quality of a signal in a measurement system. In this research, the measured SNR is the SNR signal after reconstruction. The larger the SNR value, the better the signal quality is generated. SNR is calculated in decibels (dB) and is mathematically expressed using the equation:

$$SNR = 10log\frac{P_X}{P_e} \quad (8)$$

where P_X is the original signal power, whereas P_C is the noise power.

3. EXPERIMENTAL RESULT

The data used in this research are a recording result of the dolphin ultrasound sound. This sound is recorded directly using a special ultrasound hydrophone speaker that has a long recording duration. The recorded file format is saved in wav format. In this research, the recording result data is divided into 30 sample data which still contain the ultrasound signal. The signal range value that most often appears on such 30 data is about 1 kHz - 48 kHz.

This data contains a noise that appears during the sound recording process. Therefore, it is necessary to do denoising process using wavelet in order to noise is reduced. The denoising process is done by determining the type of wavelet to be used. This research using Haar wavelet for denoising process. Then do an experiment for decomposition level 1 to 5 with thresholding type that is a hard threshold and soft threshold.

The denoising process will produce a signal that has been subjected to noise reduction based on the decomposition level and the specified thresholding type. The last step is to calculate the SNR value on the decomposition of level 1 until level 5, with soft threshold and hard threshold. If there is an SNR value of the largest among the five levels, then the test is considered complete, but if not then there is still an error during the denoising process.

The result of denoising process using wavelet decomposition of level 1 to 5 with a hard threshold is shown in Figure 2. and with a soft threshold is shown in Figure 3. Figure 2a) and 3a) ares the display of information signals when denoising has not yet been performed, which has an initial SNR of 64.1912 dB. Figure 2b), 2c), 2d), 2e), and 2f) are display of information signals that have been undergone denoising process at a decomposition level of 1 to 5 respectively. Each has an SNR value of 52.8897 dB, 52.8329 dB, 52.7966 dB, 52.8368 dB, and 52.9076 dB respectively. Figure 3b), 3c), 3d), 3e), and 3f) are display of information signals that have been undergone denoising process at a decomposition level of 1 to 5 respectively. Each has an SNR value of 52.8897 dB, 52.8205 dB, 52.8140 dB, 52.8488 dB, and 52.9410 dB respectively. Figure 4 shows the comparison of SNR values between the hard threshold method and the soft threshold method.

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

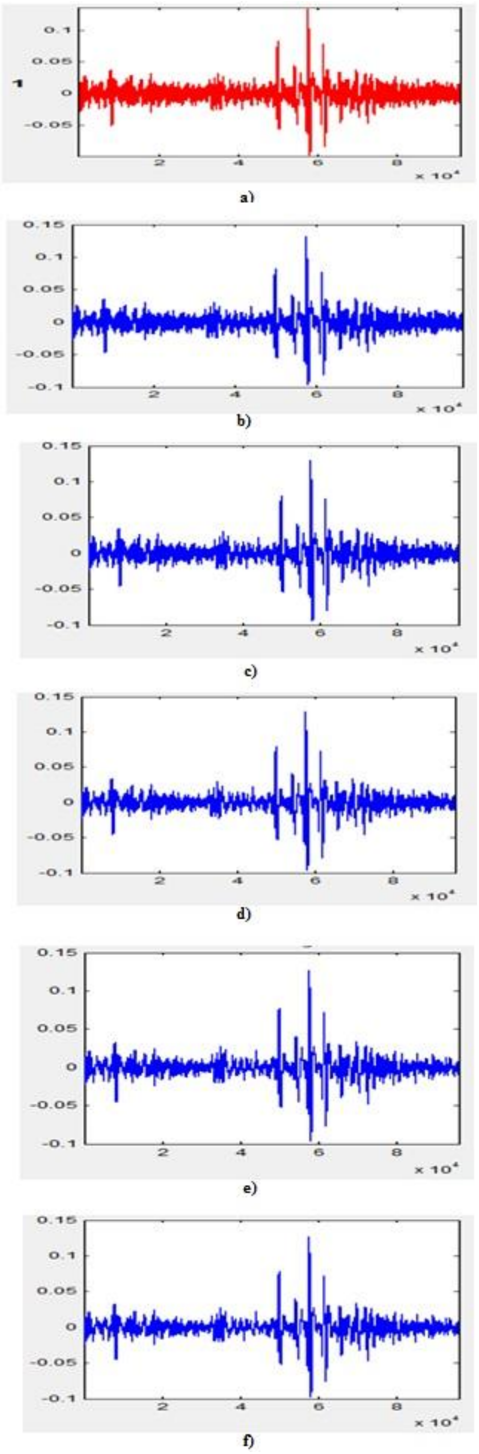

FIGURE 2. The denoising process uses wavelet decomposition successively from the original signal, level 1 to 5 with a hard threshold

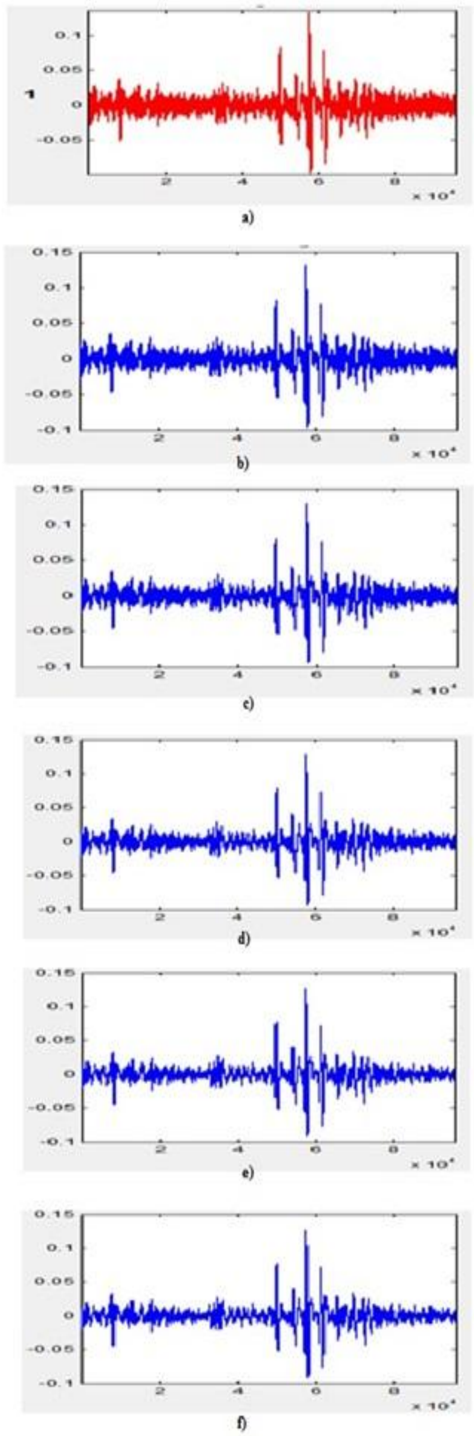

FIGURE 3. The denoising process uses wavelet decomposition successively from the original signal, level 1 to 5 with a soft threshold

The test result of 30 data of recording sample with hard threshold type for each decomposition level is shown Table 1 whereas for soft threshold type shown in table 2. Table 1 shows that the largest average SNR is achieved at Level 5 Decomposition

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

of 46,558. Similarly, from table 2 it is seen that the average SNR is also achieved at the level 5 decomposition of 46,555. The very small difference in SNR average values in both types indicates that a hard threshold is only slightly better than a soft threshold in reducing noise occurring in ultrasound waves.

Types of soft and hard threshold have their respective advantages. In the soft threshold, the noise reduction will be smoother as the value below the threshold will be eliminated while the value above the threshold will be reduced, while the hard threshold value below the threshold will be removed while the value above the threshold will remain. So the determination of the best type of thresholding will depend on the information signal you have.

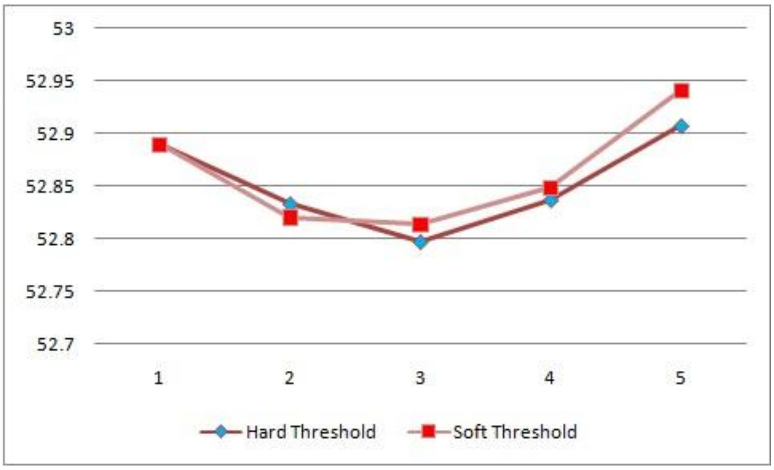

FIGURE 4. The comparison of SNR values between the hard threshold method and the soft threshold method.

4. CONCLUSION

This paper shows that the ultrasound wave denoising process can be performed using wavelet transforms. From wavelet decomposition of level 1 to 5 it appears that level 5 gives the highest average value compared to the other levels. As for the type of thresholding, the type of hard threshold gives slightly better results than the soft threshold. The determination of the best type of thresholding will depend on the information signal you have.

In the future research needs to be done for more diverse conditions such as recording time during rainfall so that the noise becomes more. Also, need to be tested for other types of wavelets in order to know the best method.

ACKNOWLEDGEMENTS

Thanks to Universitas Lampung who has provided research funding through “Penelitian Unggulan Perguruan Tinggi” scheme year Budget 2017.

REFERENCES

[1] Simpson K, Keen D, Lamb J, The use of music to engage children with autism in a receptive labelling task, Research in Autism Spectrum Disorders, Vol. 7, Issue 12, December 2013, pp. 1489-1496

[2] Fithri H, Religious therapy as one of an alternative ways in getting educational betterment for children with autism spectrum, Procedia - Social and Behavioral Sciences 29 International Conference on Education and Educational Psychology (ICEEPSY 2011), Turkey, Oct 18-22, 2011, pp. 1782 – 1787

[3] Davis TN, Scalzo R, Butler E, Stauffer M, Farah YN, Perez S, Mainor K, Clark C, Miller S, Kobylecky A, Coviello L, Animal assisted interventions for children with autism spectrum disorder: a systematic review, Education and Training in Autism and Developmental Disabilities, Vol 50(3), 2015, pp. 316–329

[4] Siewertsen CM, French ED, Teramoto M, Autism spectrum disorder and pet therapy, Advances in mind-body medicine Vol. 29, No. 2, 2015, pp.22-25

[5] Kršková L, Talarovičová A, Olexová L, Guinea pigs—The “Small Great” Therapist for autistic children, or: do guinea pigs have positive effects on autistic child social behavior?, Society and Animals, Vol. 18, 2010, pp. 13-151

[6] Md. Yusof MS, Chia NKH, Dolphin encounter for special children (desc) program: effectiveness of dolphin-assisted therapy for children with autism, International journal of special education, Vol. 27, No. 3, 2012, pp. 54-67

[7] Brensing K, Linke K, Todt D, Can dolphins heal by ultrasound?, Journal of Theoretical Biology, Vol. 225, 2003, pp. 99-105

[8] Reaz MBI, Hussain MS, Ibrahimy MI, Mohd-Yasin F, EEG signal analysis and characterization for the aid of disabled people, WIT Transactions on Biomedicine and Health, Vol. 12, 2007, pp. 287-294

[9] Choi J, Hong JW, Characterization of wavelet coefficients for ultrasound signals, Journal of Applied Physics, Vol. 107, 2010, pp. 1-6

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)