Pre-processing of Accelerometer Data for the Analysis of Adequate Footwork during Dancing using ANFIS

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***Abstract*— In this article, an elementary and effective noise cancellation technique for the analysis of proper footwork during a dance performance is proposed. An experiment was conducted on the analysis of the vibration occurred on a dance floor by obtaining data from accelerometer. The spectral pattern for respective foot movements may be helpful to analyze the dance performance. The major issue in this methodology is the impact of noise occurred due to the presence of surrounding music systems in a closed dance hall. In this proposed noise cancellation technique, we have used ANFIS to recognize the nonlinear relationship between noise occurred due to surrounding music and the interference occurred. Though interference is not directly available, we can take the measured signal from the accelerometer as a "adulterated" version of interference for training. Finally, the impact of noise on the measured signal is efficiently cancelled and the filtered signal is used for the analysis of foot movement during dance performance.**

***Keywords*— Filter, Adaptive filter, ANFIS, Accelerometer, Vibration, Noise Cancellation**

I. INTRODUCTION

Filtering is a signal processing technique where the objective is to process a signal in order to manipulate the information contained in it. A digital filter is the one that processes discrete-time signals represented in digital format. For time-invariant filters the internal parameters and the structure of the filter are fixed, and if the filter is linear the output signal is a linear function of the input signal. Once required specifications are given, the design of time-invariant linear filters entails three basic steps, firstly: the approximation of the specifications by a rational transfer function, secondly, the choice of an appropriate structure defining the algorithm, and lastly the choice of the form of implementation for the algorithm [1]. An adaptive filter is needed where either the fixed specifications are unknown or the specifications cannot be satisfied by time-invariant filters. The adaptive filters are time-varying since their parameters are continually changing in order to obtain a desired performance. Adaptive filters are considered nonlinear systems; therefore the analysis of their behavior is more complicated than those fixed filters. Soft computing is a new approach to construct smart systems. The complex real world problems require smart systems that combine knowledge, techniques and methodologies from various sources. Neuro -fuzzy is the combination of neural network and furzy logic. Neural networks recognize patterns and adapt themselves to cope with changing environments. Fuzzy inference systems incorporate human knowledge and perform inferencing and decision making. Noise is an unwanted energy, which interferes with the desired signal. It can be suppressed by using adaptive filters. But if the noise frequency is same as the original signal then sometimes it also eliminates the desired signal. Therefore, noise cancellation is used which will not affect the desired signal. The basic principle of noise cancellation using neuro-fuzzy is to filter out an interference component by identifying the nonlinear model between a measurable noise source and the corresponding immeasurable interference [2]. In this article, adaptive neuro-fuzzy inference system (ANFIS) is employed to nullify the effect of external noise in the accelerometer data during vibration analysis of the dance floor which ultimately will be used for the analysis of proper foot movement. A proper footwork may be vital for proper posture and movement of a dancer. Some foot positions and actions are traditionally considered appealing, while others are flat, although this depends on the culture. A sophisticated footwork may in itself be the goal of the dance expression.

II. METHODOLOGY

A. *Proposed model for noise cancellation*

The proposed model consists of an estimation model based on ANFIS for the interference occurred during dancing and a smoothing technique using binomial weighted average filtering. The complete proposed model is shown in the figure 1.

B. *ANFIS Structure*

ANFIS classifier modifies the premise parameters of membership functions and consequent parameters of fuzzy rules by using its learning ability from the training data-set. The structure of ANFIS Classifier built for this experimental study comprises of four different functional layers and is illustrated in figure 1. The function of each layer is explained below. The layer 2 and layer 3 are hidden layers. The number of membership functions used in the layer 1 decides the number of rules to be framed by the ANFIS classifier. Here in this case, 48 fuzzy IF-THEN rules are framed by multiplying the number of membership functions used in layer 2 for all the two inputs.

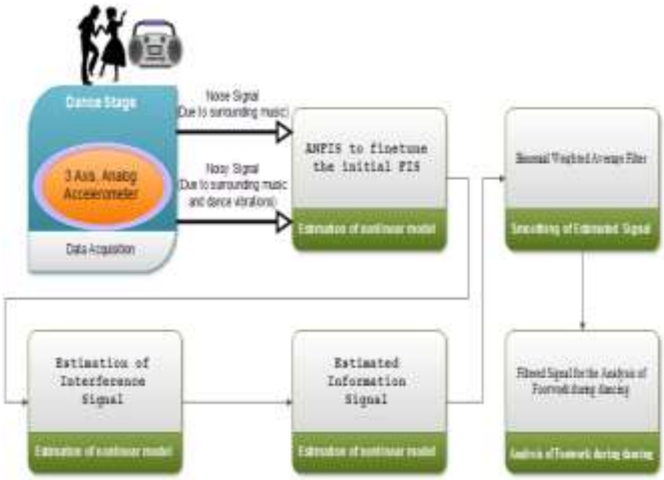

Fig. 1 Proposed estimation methodology for preprocessing of accelerometer data during dancing.

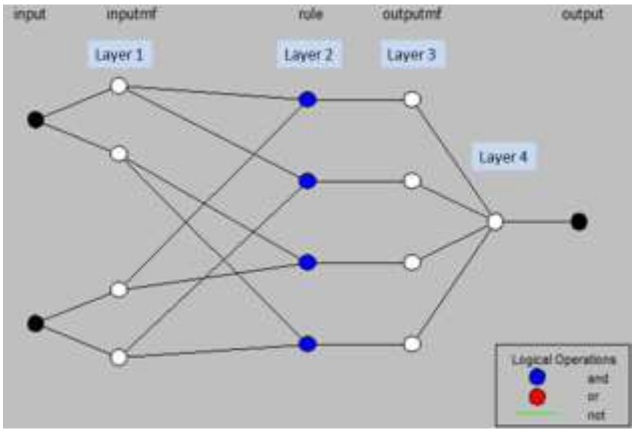

Fig. 2 Structure of ANFIS model for preprocessing of accelerometer signal.

Layer 1:

First layer is responsible for fuzzification of input feature values in the range of 0–1 under the banner of linguistic labels namely low, medium and high. The shape and magnitude of the membership function can be adjusted automatically by the ANFIS network according to the magnitude of input signals. These parameters are called as premise parameters and remains as the IF part of Fuzzy logic rules.

Layer 2:

The second layer determines number of fuzzy rules to model the training data-set. This layer acts like a multiplier and the output defines firing strength of the IF-THEN rules. This layer executes the premise part of IF-THEN rules.

Layer 3:

The parameters available in third layer are called as consequent parameters. They are the THEN part of Fuzzy logic rules. This layer executes the consequent part of IF-THEN rules.

Layer 4:

The fourth layer consists of one single node which generates the summation of all incoming signals from previous node and results in a single value. The output value of this node is responsible to determine the class of input pattern.

C. Binomial Weighted Average Filter

Other kinds of moving average filters do not weight each sample equally. It is a common type of filter which follows the binomial expansion of (1/2, 1/2) n. This type of filter approximates a normal curve for large values of n. It is useful for filtering out high frequency noise for small values of n. To find the coefficients for the binomial filter, convolve [1/2 1/2] with itself and then iteratively convolve the output with [1/2 1/2] a prescribed number of times.

Binomial filter is a weighted moving average filter, Let x_n be the input source data and y_n is the output smoothed data.

$$y_n = \sum_{k=-N_p}^{Np} b_k x_{n-k}$$

The sequence of smoothing coefficients b_k is given by:

$$b_k = \binom{2N_p}{N_p + k} / 4^{N_p} \quad (k = 0, 1, \ldots N_p)$$

and

$b_{-k} = b_k$ is the Order.

The Cutoff frequency fc is calculated by:

$$fc = \frac{2}{\pi} arccos(Ac^{1/2N_p}) \frac{fs}{2}$$

$$fs = \frac{1}{dt}$$

dt is Sampling Interval. Ac is cutoff amplitude at -6dB.

III. Results and Discussions

During the design of the noise cancellation methodology, we have implemented the ANFIS classifier to nullify the effect of surrounding noise generated by the music systems during dancing on a stage. The estimated signal can be used to analyze the foot movement during dancing. During the conduction of experiment, an analog accelerometer is connected to the dance stage and the signal is recorded using a data acquisition card (National Instruments USB DAQ 6009). The accelerometer voltage signals in X-Y-Z axis without any surrounding music are shown in the figure 3.

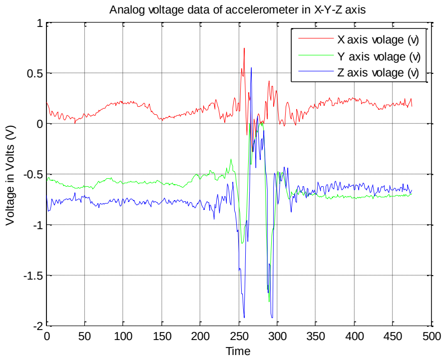

Fig. 3 The accelerometer voltage signals in X-Y-Z axis without any surrounding music.

Similarly, the individual signals of X-Y-Z axis are shown in the figure 4, figure 5 and figure 6.

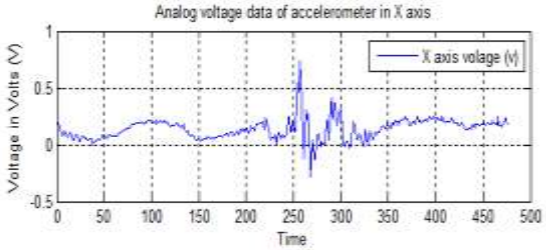

Fig. 4 The accelerometer voltage signals in X axis without any surrounding music.

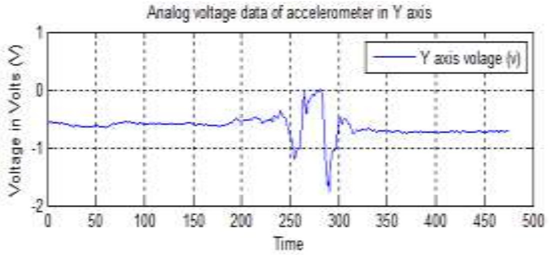

Fig. 5 The accelerometer voltage signals in Y axis without any surrounding music.

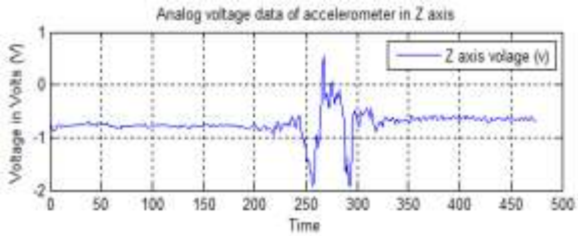

Fig. 6 The accelerometer voltage signals in Z axis without any surrounding music.

Secondly, the vibration noise generated due to the effect of surrounding music is also recorded without any dance on the stage. The figure 7 shows the voltage signal recorded during music played in the dance hall. The peak signifies the X axis voltage signal of the analog accelerometer during only surrounding music.

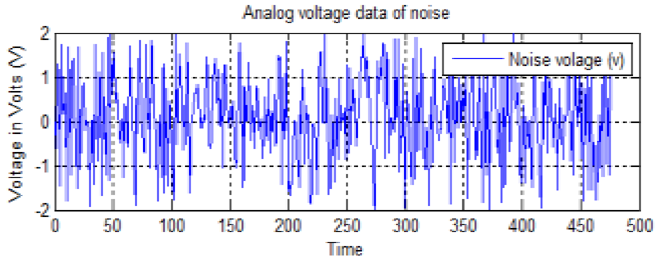

Fig. 7 The accelerometer voltage signals in X axis only with surrounding music in the dance hall.

Finally, the noisy signal was recorded when music is played and the dancing practice was continued in the hall. The noisy signal recorded by the data acquisition card is shown in the figure 8.

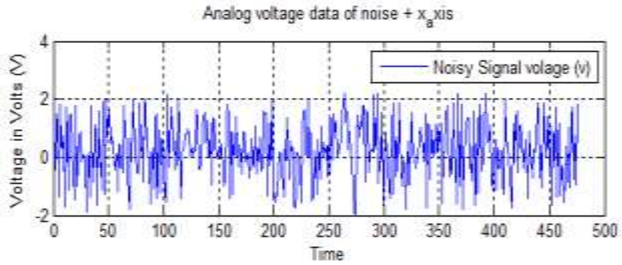

Fig. 8 The accelerometer voltage signals in X axis with surrounding music and dance practice on the stage.

The recorded signals were supplied to estimate the interference pattern occurred during dancing. The noise signal generated during surrounding music and the noisy signals during dance practice were supplied to the ANFIS model to estimate the interference pattern. The figure 9 shows the estimated interference pattern.

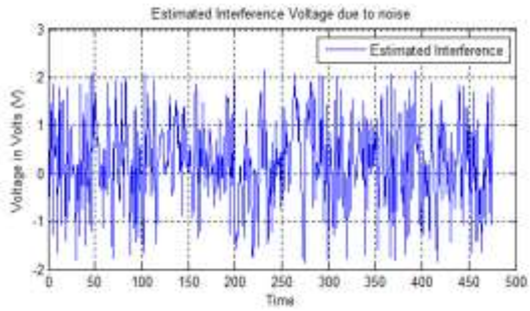

Fig. 9 The estimated interference pattern.

After training, the estimated interference is calculated using the command ANFIS model. The estimated information signal is equal to the difference between the measured signal and the estimated interference (that is, ANFIS output). The original information signal and the estimated by ANFIS are plotted. The figure 10 shows the estimated vibration data using ANFIS model.

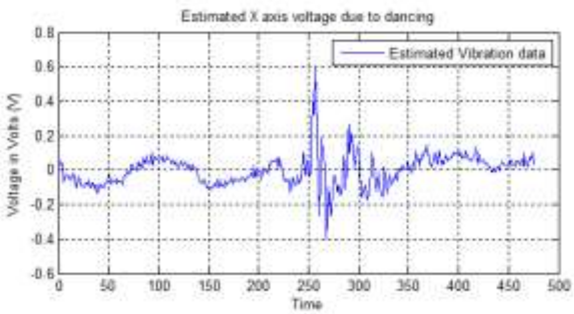

Fig. 10 The estimated information signal (Vibration data of the foot movement on the dance stage).

It can be observed from the estimated signal that the signal is not properly smoothed hence it will be difficult to analyze the footwork movement pattern. So a binomial weighted average filter is applied to the estimated signal which produces a smoothed signal which can be easily used for the analysis of footwork during dance practice. The figure 10 shows the original signal and the filtered signal with respect to the normalized frequency.

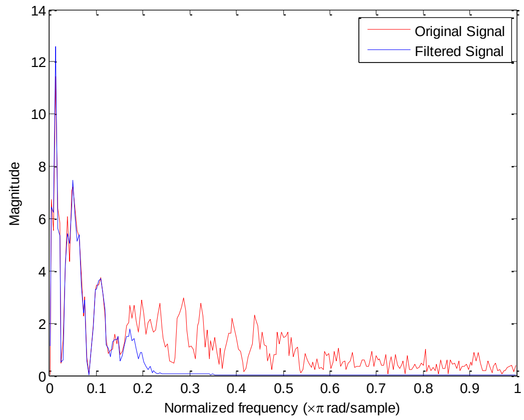

Fig. 11 The original signal and the filtered signal with respect to the normalized frequency.

Finally, the estimated X axis signal of the accelerometer is successfully filtered out which can be used for the analysis of footwork during dance practice. The Figure 12 shows the filtered signal after binomial weighted average filter.

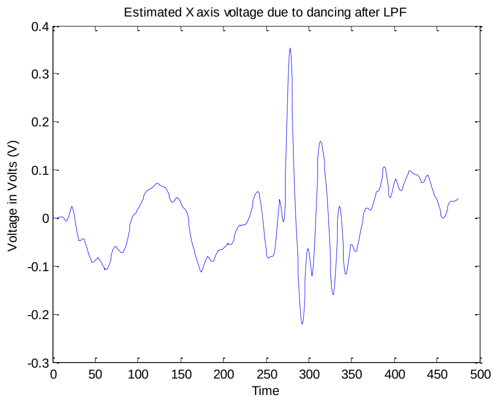

Fig. 12 The filtered signal after binomial weighted average filter.

The fuzzy logic rules based surface plot signifies the dependency of one of the outputs on any one or two of the inputs—that is, it generates and plots an output surface map for the system. The figure 13 shows the surface plot of the ANFIS rules for two inputs.

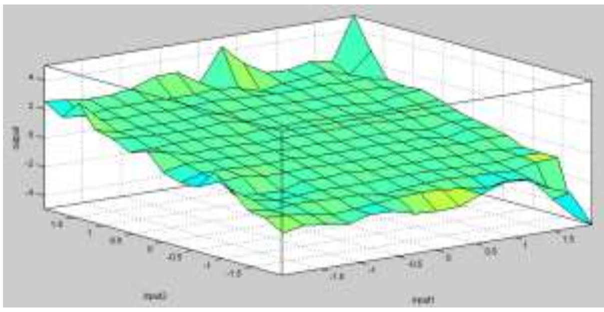

Fig. 13 The ANFIS rule base surface plot for two inputs.

IV. CONCLUSION

The ANFIS algorithm is a well-known, easy to implement and computationally cheap solution to this problem. The algorithm is successfully tested with an analog accelerometer installed beneath the dance stage. Firstly, the interference model was established using ANFIS structure and then the model is utilized to estimate the information signal. It is observed that the estimated signal correctly matches the actual information signal during dancing. Finally, a binomial weighted average filter was using to produce a smoothed signal so that it can better be utilized for the analysis of foot movement on the dance floor irrespective of the surrounding music produced by the nearby music systems. Hence it can be concluded that this methodology consisting of ANFIS model and binomial weighted average filter can help to estimate the footwork during dancing efficiently.

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