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Design of Low Pass FIR Filter Using General Regression Neural Network (GRNN)

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Abstract- With the technological evolution, great advances have been made on design techniques for various digital filters. In this paper, a type of Artificial Neural Network (ANN) called General Regression Neural Network (GRNN) is proposed to design a Low Pass FIR filter. Kaiser Window is used to prepare the data set for the training and testing of proposed General Regression Neural Network (GRNN). The performance evaluation of the proposed Neural Network (NN) is done in terms of the error between the actual and desired output filter coefficients and the filter response graphs.

Keywords- Artificial Neural Network (ANN), General Regression Neural Network (GRNN), Neural Network (NN), Radial Basis Function (RBF), Stop band Attenuation (SBA), Pass band Ripple (PBR).

I. INTRODUCTION

A filter is essentially a system or network that selectively changes the wave shape amplitude – frequency and or phase – frequency characteristics of a signal in a desired manner. Common filtering objectives are to improve the quality of a signal, to extract information from signals or to separate two or more signals. A digital filter is a mathematical algorithm implementation in hardware and/or software that operates on a digital input signal to produce a digital output signal for the purpose of achieving a filtering objective. A simplified block diagram of a real-time digital filter, with analog input and output signals is as shown in Figure 1[1].

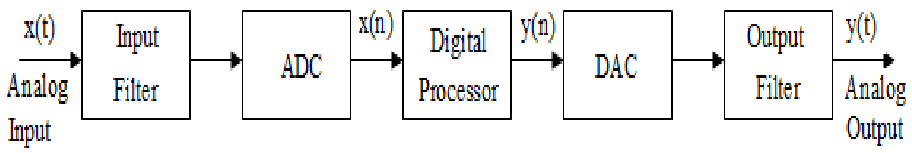

Figure 1: Block diagram of digital filter

The design of digital filter has received great deal of interest over the past decades. There are traditional methods to design a digital FIR filter, which are:-

(1) Fourier Series method
(2) Frequency Sampling method
(3) Window method

Now days there are various other design methods to design filter such as Neural Network (NN) [2-4] , Genetic Algorithm (GA)[5], Particle Swarm Optimization (PSO)[6-8] Discrete Cosine Transform (DCT)[9], Chebychev Criterion[10], etc. In present paper we are proposing General Regression Neural Network (GRNN) to design a low pass FIR. For that we firstly require a previous data set of examples from which NN can train itself. We have used Kaiser Window method to calculate the filter coefficients to prepare data set, as filter design is all about deriving the filter coefficients. The advantage of Kaiser Window is that it has ripple control parameter beta (β), which allows designer to trade-off the transition width against ripple [1]. Its window function is as expressed below:

$$w(n) = I_0\left\{\beta\left[1-\left(\frac{2n}{n-1}\right)^2\right]^{1/2}\right\}\Big/ I_0(\beta)$$

Where $I_0(.)$ is the zero order modified Bessel function of the first kind and β is the tuning parameter of the window. The value of beta (β) is determined by the stop band attenuation requirements and can be estimated by using following empirical relationship [1]

$$\beta = \begin{cases} 0.1102(A-8.7) & \text{for } A > 50 \\ 0.5842(A-21)^{0.4} + 0.07886(A-21) & \text{for } 21 \le A \le 50 \\ 0.0 & \text{for } A < 21 \end{cases}$$

Where $\text{Attenuation } A = -20\log_{10}\delta dB$ and $\delta = \text{minimum}(\delta_p, \delta_s)$

The order of the filter is calculated as

$$M = \begin{cases} \dfrac{A-8}{14.36df} + 1 & \text{for } A > 21 \\ (0.922/df) + 1 & \text{for } A \le 21 \end{cases}$$

II. ARTIFICIAL NEURAL NETWORK (ANN)

An Artificial Neural Network (ANN) also known as "Neural Network (NN)", is a computational model based on the structure and function of biological neural network. In other words ANN is computing system which is made up of a number of simple processing elements (the computer equivalent of neurons, Nodes) that are highly interconnected to each other through synaptic weights. The number of nodes, their organization and synaptic weights of these connections determine the output of the network. ANN is an adaptive system that changes its structure/weights based on given set of inputs and target outputs during the training phase an produces final outputs accordingly. ANN is particularly effective for predicting events when the network have a large database of prior examples to draw. The common implementation of ANN has multiple inputs, weight associated with each input, a threshold that determine if the neuron should fire, an activation function that determine the output and mode of operation. The general structure of a neural network has three types of layers that are interconnected: input layer, one or more hidden layers and output layer as shown in Figure 2[11-13].

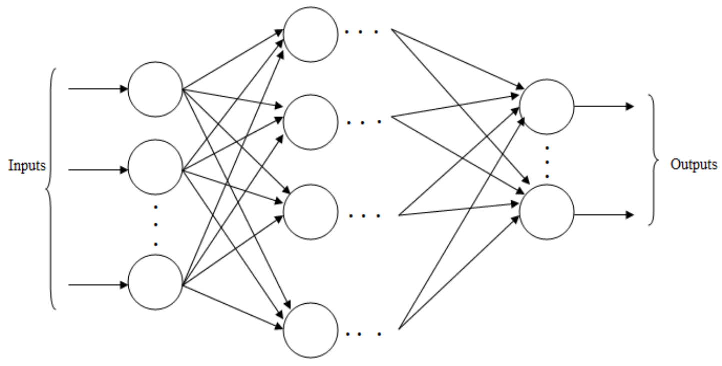

Figure 2: General Structure of Neural Network

There are some algorithms that can be used to train an ANN such as: Back Propagation, Radial-basis Function, and Support Vector Learning, etc. The Back Propagation is the simplest but it has one disadvantage that it can take large number of iterations to converge to the desired solution [14]. In Radial Basis Function (RBF) network the hidden neurons compute radial basis functions of the inputs, which are similar to kernel functions in kernel regression [4]. Specht has popularized kernel regressions, which he calls a General Regression Neural Network (GRNN) [14]. General Regression Neural Network (GRNN) is a variation of Radial Basis Function (RBF) network that is based on the Nadaraya – Watson kernel regression. The main features of GRNN are fast training time and it can also model non-linear function [15]. GRNN being firstly proposed by Sprecht in 1991 is a feed forward neural network model base on non linear regression theory. It approximates the function through activating neurons [16]. The network structure of GRNN consists of three layers: input layer, radial basis hidden layer and linear output layer as shown in Figure 3 [17]. The transfer function of hidden layer is Radial Basis Function.

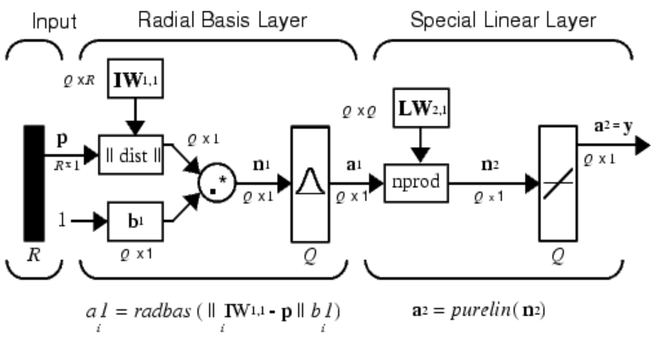

Figure 3: Network structure of GRNN

III. PROPOSED GRNN MODEL

In proposed GRNN model of low pass FIR filter inputs are: stop band attenuation (SBT), transition width (TW), pass band ripple (PBR), sampling frequency (SF), cut-off frequency (Fc) and the outputs are filter coefficients h(n). The filter specifications as input and their range is given below:

(a) SBT: 40-45 db
(b) TW: 55-60 Hz
(c) PBR: 0.05–0.1 db
(d) SF: 700-750 Hz
(e) Fc : 70-75 Hz

Proposed model using these filter specifications as input and filter coefficients as output is as shown in Figure 4.

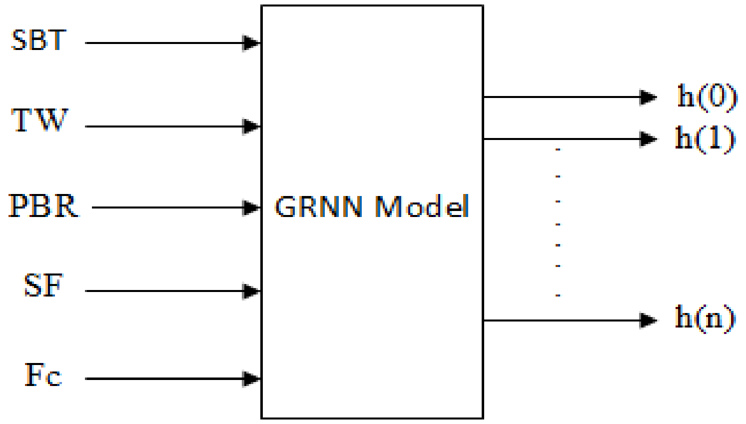

Figure 4: Proposed GRNN model for filter design

The proposed model has been trained using a data set prepared with Kaiser Window. Now, GRNN can be used to design the low pass FIR filter for unknown input specifications.

IV. Results

The trained network has been tested using four sets of specifications as shown in Table 1. The Figure 5, 6, 7&8 shows the graphs of filter response of Kaiser Window and GRNN for different input sets shown in Table 1.Table 2 shows the error in calculating the filter coefficients for these input sets using GRNN.

TABLE 1: Different Sets of Input Parameters

Input Parameters	Set 1	Set 2	Set 3	Set 4
SBT	43	40	43	44
TW	56	56	58	57
PBR	0.0824	0.0774	0.0684	0.0754
SF	747	737	739	723
Fc	74	73	73	70

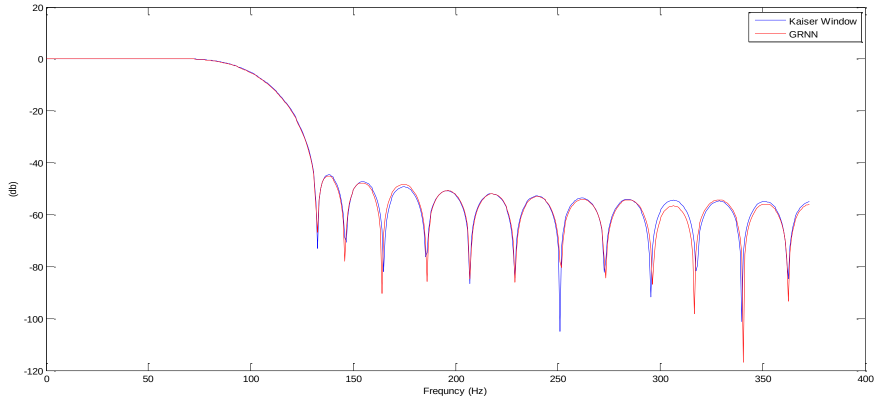

Figure 5: Filter response of Kaiser Window and GRNN for input Set 1

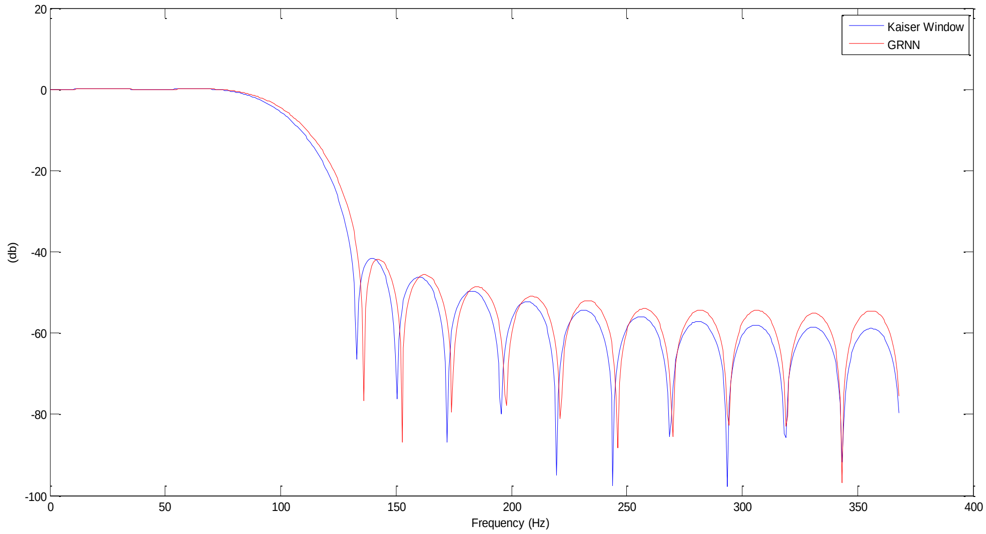

Figure 6: Filter response of Kaiser Window and GRNN for input Set 2

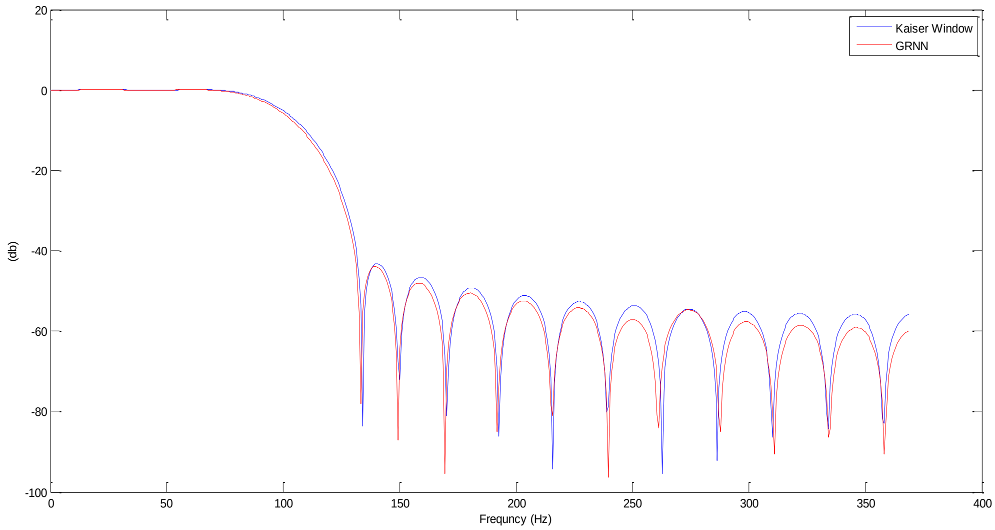

Figure 7: Filter response of Kaiser Window and GRNN for input Set 3

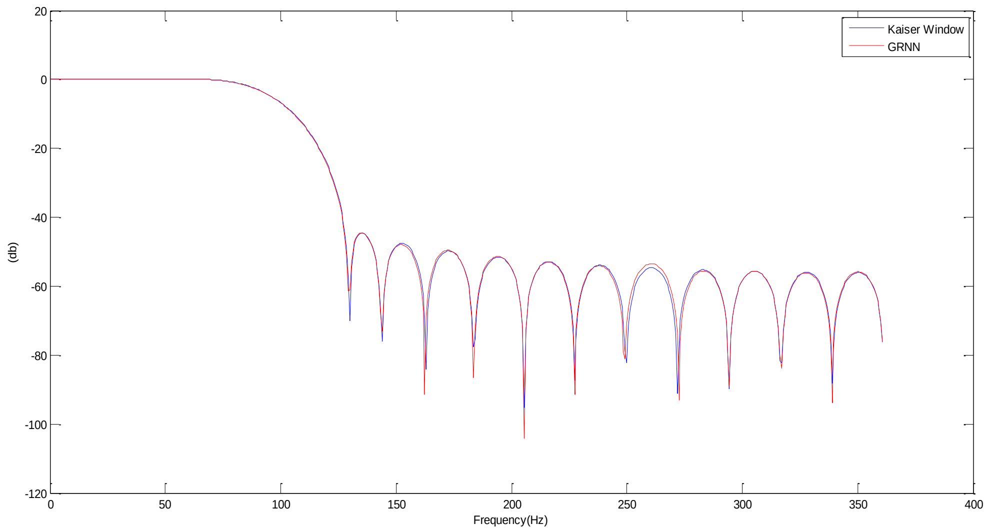

Figure 8: Filter response of Kaiser Window and GRNN for input Set 4

TABLE 2: Error Between Filter Coefficients

h(n)	SET 1	SET 2	SET 3	SET 4
h(0)	0.0001	0.0009	0.0005	0
h(1)	0.0001	0.0011	0.0004	0.0001
h(2)	0.0001	0.0002	0.0001	0.0001
h(3)	0	0.0018	0.0011	0.0001
h(4)	0.0003	0.0029	0.0016	0.0003
h(5)	0.0005	0.0019	0.0011	0.0003
h(6)	0.0002	0.0014	0.0007	0.0001
h(7)	0.0002	0.0044	0.0025	0.0003
h(8)	0.0006	0.0045	0.0028	0.0005
h(9)	0.0006	0.0008	0.0011	0.0004
h(10)	0.0002	0.0041	0.0018	0
h(11)	0.0004	0.0066	0.0039	0.0005
h(12)	0.0008	0.0041	0.0034	0.0006
h(13)	0.0008	0.0017	0.0005	0.0004
h(14)	0.0002	0.0064	0.003	0.0002
h(15)	0.0007	0.0064	0.0046	0.0007
h(16)	0.0009	0.0017	0.003	0.0007
h(17)	0.0007	0.0041	0.0005	0.0002
h(18)	0.0002	0.0066	0.0034	0.0004
h(19)	0.0008	0.0041	0.0039	0.0006
h(20)	0.0008	0.0008	0.0018	0.0005
h(21)	0.0004	0.0045	0.0011	0
h(22)	0.0002	0.0044	0.0028	0.0004
h(23)	0.0006	0.0014	0.0025	0.0005
h(24)	0.0006	0.0019	0.0007	0.0003
h(25)	0.0002	0.0029	0.0011	0.0001
h(26)	0.0002	0.0018	0.0016	0.0003
h(27)	0.0005	0.0002	0.0011	0.0003
h(28)	0.0003	0.0011	0.0001	0.0001
h(29)	0	0.0009	0.0004	0.0001
h(30)	0.0001	0	0.0005	0.0001
h(31)	0.0001	0	0	0
h(32)	0.0001	0	0	0

V. Conclusion

The present paper has proposed the General Regression Neural Network (GRNN) for the design of low pass FIR Filters rather than using the complex calculative traditional methods. GRNN is easy and fast method to design a low pass FIR filter once trained properly. The filter response graphs are almost similar for both Kaiser Window and proposed GRNN model. Also the error between GRNN calculated filter coefficients and desired filter coefficients is very less which validates the proposed model.

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