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Design of An Adaptive Neuro-Fuzzy Inference System for Floating Point Function Generation using CORDIC Algorithm

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Abstract: ***In this paper a digital system architecture for ANFIS (Adaptive Neuro-Fuzzy Inference System) using Cordic algorithm is presented. Co-ordinate Rotation Digital Computer (CORDIC) is a device which is excessively used in recent DSP applications, due to its simple approach. Its well designed approach utilizes only add and shift operations instead of multipliers. The proposed system will be used for floating point function generation. Firstly, a floating point function is chosen and training is carried out which is called as the off-line training using MATLAB ANFIS. This is used to get the parameters like premise and consequence of the fuzzy rules. Simulation is performed to verify the operation of the system for given input data.***

Keywords: Neuro-fuzzy, ANFIS, CORDIC, Digital System, floating point.

1. Introduction

The two theory Neural networks and neuro fuzzy inference systems have been studied by many researches. These two theories combine together for the development of neuro-fuzzy system. The Adaptive neuro-fuzzy Inference system (ANFIS) is one of the example for Neuro-Fuzzy based system. ANFIS are functionally equivalent to fuzzy inference systems. It uses Hybrid learning Algorithm for training purpose.

The Coordinate Rotation Digital Computer i.e. CORDIC algorithm is a practical and classical method for the computation of vector rotation. Volder introduced CORDIC Several decades ago which was further generalized by Walther.

The trigonometric functions, like sin and cosine can be calculated using CORDIC algorithm, which are fundamental operations functions to many digital signal processing applications. Moreover, it has been extended to hyperbolic functions. High-speed data paths in embedded processors and microprocessors contain complex floating-point arithmetic units which have a important role in the processor's performance. A floating-point system can be used to represent, numbers of different orders of magnitude e.g. the distance between galaxies or the diameter of an atomic nucleus can be expressed with the same unit of length. The result of this dynamic range is that the numbers that can be represented are not uniformly spaced; the difference between two consecutive representable numbers grows with the chosen scale Floating Point support for floating point operations in half, single and double-precision floating point arithmetic. The floating point capabilities performance for floating point arithmetic used in automotive powertrain and body control applications, imaging applications such as scaling, transforms and font generation in printing, 3D transforms, FFT and filtering in graphics. This paper organized in such a way as section II explained the previous research in the related work, Section III & IV describe the brief ANFIS description and proposed architecture and Section V describes the conclusion.

2. Related Work

In [1] the architecture for a two input and one output zero order ANFIS is described for digital system. The system is designed and implemented on FPGA so as to generate and test the function which is nonlinear in nature. ANFIS with the triangular membership function is also used. The final designed system is fully explained using VHDL (VHSIC Hardware Description Language) and is implemented on an FPGA were dedicated resource are not used.

In [2], the CORDIC algorithm is used to calculate the trigonometric functions such as sine and cosine, which are used in real time digital signal processing very extensively, to get the trigonometric functions as processor's instructions. Many hardware structures in combination with software are used and the flexibility of FPGAs can be used to meet system performance requirements.

In [3] Coordinate Rotation Digital Computer (CORDIC) algorithm can be used to realize the cosine law. The implementation is based on Binary Floating-Point Arithmetic. Radio frequency identification (RFID) and its application is proposed to travel from one location to other location. Floating arithmetic operation is verified and implemented on FPGA using a proposed cordic architecture. The cosine law has been successfully implemented. CORDIC algorithm enhances the performance of a location awareness system and flexibility.

In [4] the high performance and hardware efficient coordinate rotation digital computer processor structure. This approach completely eliminates the requirement of

ROM constant arctangent values. A power saving has been achieved in this system.

In [5] CORDIC computing technique which is suitable for use in special-purpose computer in which majority of the computation involve trigonometric relationships is used. The only difference is the majority of computation which are involved in the trigonometric expressions relationship.

In [6] a unified algorithm is described which is used for calculation of elementary function that includes multiplication, division, sin, cos, and hyperbolic function due to the capability and accuracy of the high speed system. The use of shifter to carry out the multiplication in practical application is done in this paper.

In [7] work dealt with enhancement of CORDIC algorithms .The proposed approach provides a first actual parallel version for the CORDIC rotator by improving the algorithm. CORDIC algorithm introduces a parallel rotator which is used to rotate used for rotating for more than one micro-rotation angle per time.

In [8] hardware efficient architecture by using CORDIC algorithm is used for the calculation of sin and cosin function. ASIC implementing of CORDIC algorithm based DDFS which has low resource utilization and power consumption. Solution for the high speed VLSI architecture is mapped from algorithm which is used for real time signal processing.

In [9] ANFIS can be used to construct input output mapping based on the knowledge of human. Hybrid learning procedure, the proposed architecture can rectify the fuzzy if-then rules which are obtained from the user to explain the input-output behavior of a complex system.

3. Brief Anfis Description

The Adaptive Neuro-Fuzzy Inference System is equivalent to a fuzzy inference system that uses a hybrid learning algorithm to construct an input output relationship. The structure which shows ANFIS is described in the figure below. It is composed of layers which has in all five layers and the square node in the first layer and the fourth layer indicates the adaptive nodes.

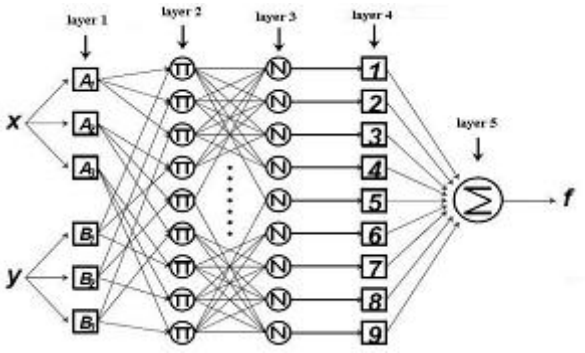

Figure 1: Two-input one output zero order ANFIS

The figure shows the five layers the first layer output are the membership values which correspond to the membership functions and then, these membership values obtained from the output of the first layer are multiplied in the second layer to obtain the firing strength or weight. In third layer, the ratios of the firing strengths to the sum of all rules firing strengths are determined. In the fourth layer, all these values are multiplied by the earlier occurring parameters. Finally, all the incoming signals are added in the fifth layer.

4. Proposed Architecture Design

Architecture Description

The proposed ANFIS system is divided in four blocks that can be seen in figure 2 below. These blocks comprises of the Fuzzifier, Permutator, Inference and Defuzzifier.

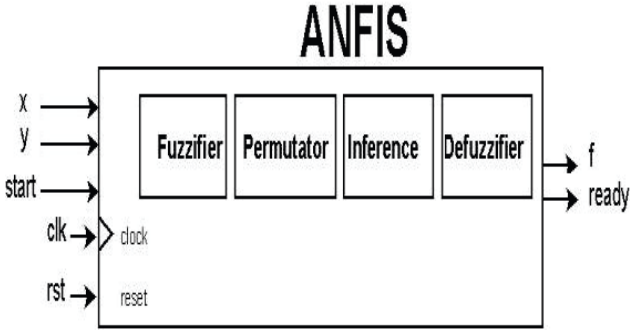

Figure 2: Proposed ANFIS block diagram

B. CORDIC algorithm

This algorithm gives a finite list of instructions that are used for calculating any particular function. As initial state and initial input is assumed to be empty, the instructions describe a method of computing that, when any instruction is executed it proceeds through a number of finite states which are successive and well defined, in the end producing output finishes at a final state. The transition from one state i.e. initial state to the final state or next state is not necessarily deterministic in some algorithms random input are used that are known as randomized algorithms.

This basic principle is applied in two operating modes:

1) The rotation mode, where the input vector is rotated until the θ target rotation angle is reached;
2) The vectoring mode, where the input vector is rotated until it reaches the x-axes by zeroing its y component in order to obtain the vector module and phase

To calculate the sine and cosine functions, the CORDIC algorithm in rotational mode is used. The initial conditions are

$$x_0 = 1/G_n$$

$$y_0 = 0$$

Using these initial conditions, equation reduces to:

$$x_n = cos(\theta_0)$$

$$y_n = sin(\theta_0)$$

5. Results Analysis

The proposed system tested and got experimental results which are shown in snapshot. The inputs are provided through neuro fuzzy fitting tool to get the output wave forms which has least mean square values. We have provide the input of the sin and the cosine angles which gives the output as required.

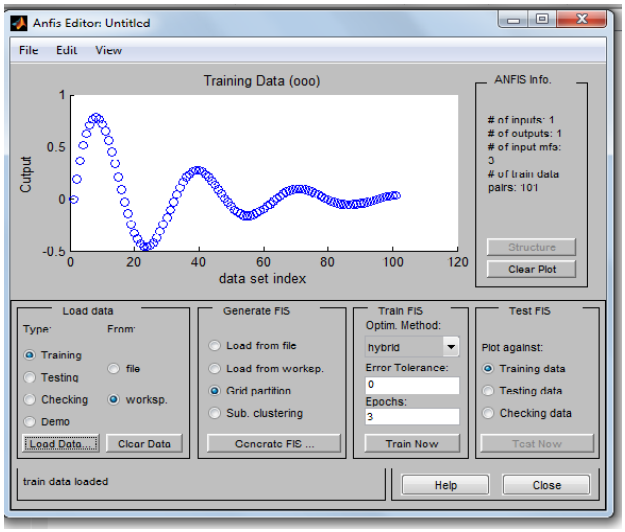

Figure 3: ANFIS output

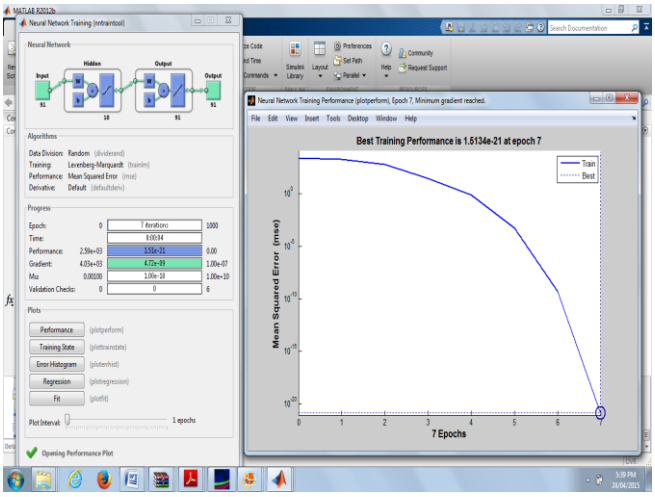

Figure 4: Training Performance

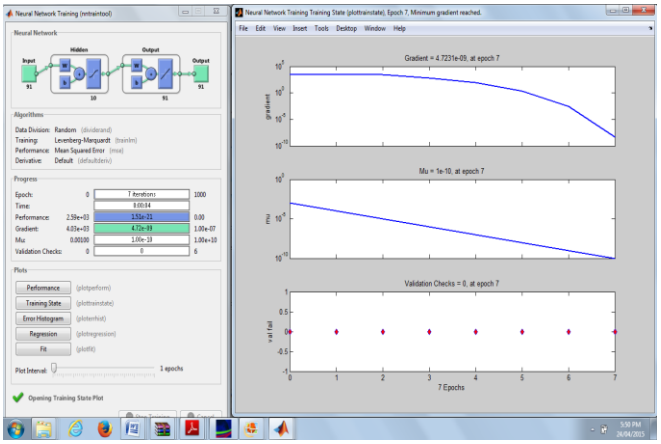

Figure 5: Training State

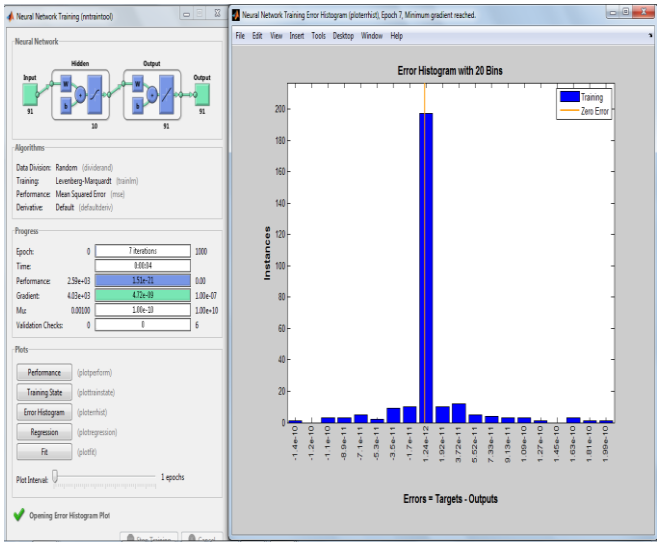

Figure 6: Error Histogram

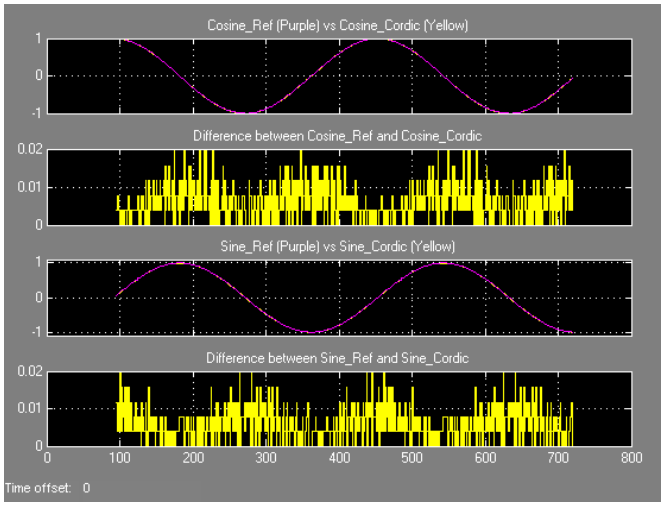

Figure 7: Sine-cosine output of CORDIC

6. Conclusion

In this paper ANFIS is studied which is a Neuro-fuzzy system used for floating point function generation using the CORDIC algorithm. The digital system architecture for a two input and one output zero order ANFIS is studied in this work. Using MATLAB the ANFIS desired output is generated. With the graphs that also include performance.

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