TRANSIENT REDUCTION ANALYSIS using NEURAL NETWORKS (TRANN)

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ABSTRACT

Our telemetry department has an application for a data categorization/compression of a high speed transient signal in a short period of time. Categorization of the signal reveals important system performance and compression is required because of the terminal nature of our telemetry testing. Until recently, the hardware for the system of this type did not exist. A new exploratory device from Intel has the capability to meet these extreme requirements. This integrated circuit is an analog neural network capable of performing 2 billion connections per second. The two main advantages of this chip over traditional hardware are the obvious computation speed of the device and the ability to compute a three layer feed-forward neural network classifier. The initial investigative development work using the Intel chip has been completed. The results from this proof of concept will show data categorization/compression performed on the neural network integrated circuit in real time. We will propose a preliminary design for a transient measurement system employing the Intel integrated circuit.

INTRODUCTION

A variety of electrical signals are generated during telemetry flight testing. One set of testing, destructive testing, has a limited bandwidth where only a small amount of data can be transmitted to the ground stations. The system shown in this paper uses a neural network to categorize the pulse shape and generates a few bits of data representing the category to send back to the ground station. A description of the data set and neural network is given. Also a brief overview of the hardware used is given. The process of obtaining a neural network and downloading the Intel IC is described along with the results.

SYSTEM INFORMATION

SIGNAL CHARACTERISTICS

The data set used for this study included 410 pulses which represent 8 different pulse categories illustrated in Figure 1. A normal pulse simulated from actual signal information was the basis for our 8 categories. Two failure modes (partial drop-out and drop-out) were found in signal data and are represented in our pulse categories. The 8 categories are used to distinguish between the normal pulse and two failure modes with and without time skew. The data set included variation in amplitude from 50 to 150% with random noise added. As much deviation as possible was given in each category without moving into adjacent classes. An exact count of each class of data pulses is given in Table 1.

Table 1

Composition of the 8 Categories in the Data Set

Normal	Drop-out	Partial Drop-out
41 early	48 early	60 partial
39 mid	112 early-mid	
20 late	60 mid	
	30 late	

NEURAL NETWORK

The neural network used for the categorization problem consisted of a 64 input three layer feedforward network with 8 outputs (one for each category). The internal layer was constructed with 64 hidden nodes. The initial training and setting of the weights was done using neural network software provided with the Intel development system. A back propagation algorithm was used in setting the weights. The back propagation method is a feedforward non-linear supervised learning routine.

In a feedforward network the signal inputs are introduced to the first layer of the neural network. The signal propagates through the layers in a forward direction. Each node in the hidden and output layer compute their own output by

$$x_j = f(\Sigma_i w_{ij} x_i)$$

where x_i is the output of the previous layer's node, w_{ij} is the weight between nodes I and j, and the sum is over the number of nodes feeding into node j. The function f() is a nonlinear operator which is a smooth, monotonically increasing sigmoid function given by the following equation

$$s(x_j) = (2/(l+e^{-x})) - 1.$$

The network learns by having local error signals propagate backwards to the layers of neurons during training. The network is presented with the data set and the appropriate output value. The algorithm tries to minimze the error between the networks guess (Pattern) and the true output value (Output). The equation used to find the error in the software simulator is

$$\text{Error} = l/2*(\text{Pattern-Output})^2$$

The weights are adjusted by back propagation which takes the following equation

$$\Delta W_{ij} = \mu * x_I * \text{Error}.$$

where μ is the learning rate (a value between 0 and 1). [1,2]

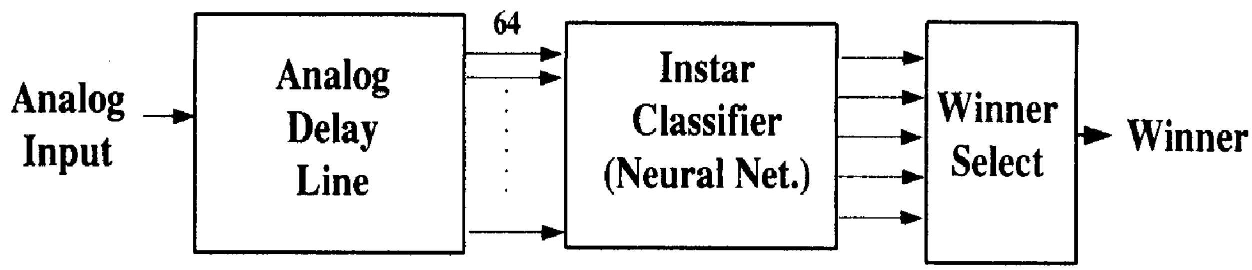
The Intel circuit used is an analog neural network chip (ETANN 80170NX). This chip has the capability of performing the above neural network in 6 microseconds with a single chip. The neural network chip can perform 2 billion connections per second where one connection is equivalent to a multiply/accumulate in Von Neumann digital computing. The chip contains 10,240 programmable weights which are stored in the form of analog charges using an Intel patented technology called CHMOS III EEPROM.[3]

The Intel chip does have some limitations. The ETANN IC has relatively low precision of 7 bits which is equal to 128 quantization levels so there is a limited dynamic range which makes it less precise than a computer simulated neural network. The physical size of the ETANN chip may present problems in our telemetry system. The IC is a 208-pin grid array which is 2.25 square inches. Also a concern was raised as to the retention time of the stored weights. Intel specifies a 10 year life before the analog weights drift significantly.

SYSTEM OVERVIEW

The complete system consists of an analog tapped delay line which samples the incoming pulse data. These quantized analog values are stored and clocked into the Intel chip which performs the categorization. The last stage is a comparator network which selects the winner which corresponds to the category with the maximum value. This complete system is shown in Figure 2 and must be used as the final proof of concept for the telemetry application.

Figure 2: System Diagram



IMPLEMENTATION

NEURAL NETWORK SIMULATION

Using the development system provided by Intel, a neural network was created with 64 inputs, 64 hidden nodes, and 8 outputs. To train the neural network, a tolerance of how close the allowable output is from the input must be decided. For example, a tolerance of 90% means that if the desired response is 1 a value of .9 is acceptable but a value of .89 would fail. A tolerance of 80% was used which took three hours to generate the appropriate weight file. This network was tested to insure correct responses on all of the data set. Another parameter that must be adjusted is the learn rate. The learn rate is how fast the network will converge upon the correct answer. This rate corresponds to the size of the jumps the weight matrix will take for the next set of guesses. With too large of a learn rate the network may never converge because the jumps may be too large to descend to the optimal point. The learn rate was adjusted with larger values in the beginning decreasing to smaller values as the network converged.

DOWNLOAD NEURAL NETWORK

The process of taking the computer generated weights and downloading on the chip is very easy with the development system. A simple software command downloads the weights to the Intel chip as would be done with an EPROM. The chip must now go through it's own training cycle hooked up to the development system. This again took several hours to adjust the weights on the chip for it's optimal performance. The chip was tested to insure that all of the data set was correctly identified with the neural network on the chip. Therefore, the chip correctly identified all pulses from the data set.

CONCLUSION

A neural network based system has been shown to be able to perform on-board pattern recognition to assess transient pulse shape characteristics. A three stage system is needed to quantize the pulse, perform the neural network, and pick the winner. Each of the individual stages have proven to be successful. A printed wiring board will be developed for the complete system in the near future. The Intel neural network IC allows fast computations which is important in destructive testing. This is just one application of neural networks and there will hopefully be many more in the future.

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