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THESIS

APPLICATION OF NEURAL NETWORKS
TO THE F/A-18
ENGINE CONDITION MONITORING SYSTEM

by

Joseph Thomas Gengo

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A back propagation and back propagation/Kohonen network were successfully tested in recognizing the various conditions with data previously unseen by the networks. Both networks demonstrated promise in predicting failures although not enough data was available for conclusive results.

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APPLICATION OF NEURAL NETWORKS TO THE F/A-18 ENGINE CONDITION MONITORING SYSTEM

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MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

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September 1989

ABSTRACT

Neural networks were applied to the Engine Condition and Monitoring System of the F/A-18 aircraft. Due to recent fleet experience with compressor blade failures in flight, neural networks were applied to three engine conditions; flameout due to compressor failures, normal operating conditions, and low oil pressure conditions. An attempt was made to predict compressor failure using the neural networks.

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The reader is cautioned that the computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logical errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. THE PROBLEM

The Navy's newest fighter and attack aircraft, the F/A-18, has in recent years been experiencing catastrophic engine loss due to material failure of engine compressor blades. The solution to the problem, which is still under investigation, has been to reline the compressor wall with a stronger material to prevent the failed blade from departing the compressor section via the wall, causing damage to the rest of the aircraft and possibly the other engine. This solution has limited the failure to the affected engine, providing the pilot an opportunity to return the damaged aircraft safely.

This study looks at the use of neural networks to recognize the flameout condition and the ability of neural networks to predict failures. Data used for this study was actual F/A-18 engine data obtained from the F/A-18 Engine Condition and Monitoring System (ECAMS) archives [Appendix 1]. The study also involves the use of two commercially available programs, *NESTOR* and *NEURAL WARE*.

B. WHAT ARE NEURAL NETWORKS?

Early research in neural networks was conducted in the 1940's by W. Pitt, W.S. McCulloch, and D. Hebb who developed neural models. In the early 1960's crude computers were used to model the brain in simple pattern recognition. Today neural networks are continually applied to new applications with more software becoming available.

Neural networks, which are a form of parallel distributed processes (PDP),can be described as simple processing elements which are connected by weighted inputs. A simple network is shown in Figure 1. The input layer is the lowest layer, the

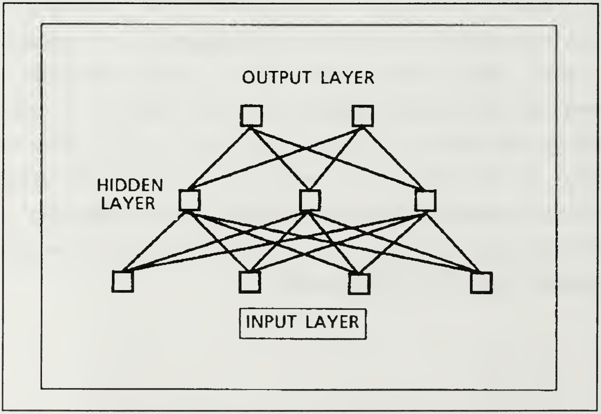

Figure 1. A simple neural network.

output layer the uppermost layer, and the hidden layers are sandwiched in-between. Except for the input layer, processing elements receive inputs from a variety of other elements, process this data with a specified algorithm, and send the results via the specified connections, to other elements higher in the chain.

The network is 'trained' on patterns supplied by the user. Training is a process where patterns are introduced with a desired output. The network learns by altering the connections among elements and the weightings of these connections to obtain the desired output. Since the algorithm of the element is not allowed to change, the weights of the connections must be altered. Training is completed when a desired level of error is reached. Error is defined as the difference between the desired output and the actual output. Training does not involve storage of data in specified memory locations. Network knowledge is contained in the weighted connections.

Learning is classified as supervised and unsupervised. Supervised learning applies to the situation where a pattern is presented to the system along with a desired output. The system is adjusted to respond with the desired output when the pattern is resubmitted. Unsupervised learning has no desired output and therefore, the network does not know what the correct response is. All networks in this study use supervised learning.

There are eight major aspects of a parallel distributed processing model as defined by Rumelhart, Hinton, and McClelland: [Ref. 1]

1. Processing Units
2. State of Activation
3. Output Function for Each Unit
4. Pattern Connection Between Units
5. Propagation Rule
6. Activation Rule (Transfer Function)
7. Learning Rule
8. An Environment

Each of these aspects will be considered in turn.

1. Processing Units

Processing units are the means by which patterns can be defined or features described. If the input pattern is considered a vector, the processing units represent the components of that vector. They are simple devices which receive input signals and produce an output signal (or value) which may be transmitted to other processing units. These units do not work sequentially but rather can carry out their computations at the same time (or in parallel).

Processing units are grouped together into three types of processing layers; input layer, hidden layers, and the output layer. The input layer provides a method of introducing a pattern to the network. The output layer exhibits the results from the network. Hidden layers convert inputs to outputs but the hidden layer inputs and outputs are not seen outside the system.

2. State of Activation

The state of activation is the status of the system at a specified time. A pattern is introduced at the input layer and a new pattern is produced at the output layer which is a modified representation of the input pattern. The status of system is the processing layer's representation of the input pattern at that specified time.

This state of activation provides the signal strength of the processing element's connection to its neighbor. The signal strength may be equal to the activation level or may be based on a threshold level where the activation must exceed a specific value before a signal is sent.

3. The Output Function

The output function refers to any modification to the outputs of the activation rule. It is simply a scaling factor used to increase or decrease the output value. Generally, the scaling factor is one.

4. Pattern Connection Between Units

The nervous system of the network is the pattern connectivity. The connections between units determines how the system learns and responds to inputs. Limiting connections provides feature extraction by restricting components of the input vector to the processing element.

5. Rules of Propagation

The rules of propagation are the methods of combining the inputs to the processing element to produce a net input. Inputs may simply be summed over all the connections or a more complex algorithm may be used.

6. Activation Rules

Activation rules, or transfer functions, transform inputs to the layer to outputs via a user defined algorithm. The algorithm uses the net input to form a new state of activation. The previous state of activation may be involved in the transfer function or a threshold value may be defined which requires a minimum value of the net input before an output is generated. Activation values of the units may be continuous and take on any real value or may be discrete and limited to values of zero or one.

7. Learning Rules

Learning rules are designed to change the patterns of connectivity based on experience. The strengths, or weighting, of connections can be modified to produce desired states of activation in the following layers. By modifying the strength of a connection to or from zero, the effect is the same as deleting or adding a connection.

8. The Environment

The environment of the system must be tuned to the types of patterns presented. Some systems are designed strictly for linear independent vector patterns, others for orthogonal vector patterns, and still others will accept any arbitrary patterns.

II. THE F/A-18 AND NEURAL NETWORKS

As stated earlier, the F/A-18 has recently been suffering from catastrophic engine failures due to problems with compressor blades. When the blades fail, fragments are sent through the engine causing severe damage to the entire engine. If it was known in advance that the compressor was about to fail, the compressor section could be removed and replaced, thus saving the engine. The Navy could realize great monetary savings.

Neural networks provide the means of predicting a major failure. Simply stated, neural networks are pattern identifiers. If the engine parameters are considered a pattern, neural networks posses the capability of sensing small changes which when coupled with other indications suggest potential failure.

The F/A-18 was chosen for this study because of the availability of engine data. The F/A-18 is one of the first aircraft in the Navy inventory to be built with an ECAM system installed during production. As a part of the aircraft procurement package, an archive was established and is constantly updated by the fleet. With the recent rash of compressor failures, data was easy to obtain.

The study began using the software *NEURALWORKS PROFESSIONAL II* to develop a back propagation network. The first network designed was trained and tested with all the available data (1755 total patterns) to ensure that the network was trainable. Once proven successful, the back propagation network was trained on a reduced amount of data and tested on all 1755 patterns. The back propagation network was expanded to three outputs, trained, and tested. The network was also modified with a Kohonen layer, trained and tested for both two and three outputs. Another software package, *NESTOR*, was attempted to provide a third network for study.

III. METHODS OF ANALYSIS

A. BACK PROPAGATION METHOD USING THE CUMULATIVE DELTA RULE

The cumulative delta rule is a variant of the generalized delta rule which is used to modify the weights of connections between elements to produce a desired output. To explain how these weights are adjusted, consider a training pattern (vector) that is submitted to the input layer (see Figure 1). Each component of the input vector is connected to each element of the first hidden layer. Each of these connections is weighted, although not necessarily equally weighted. Each element in the hidden layer is in turn connected in a similar way to the next hidden or output layer. The net input to the processing element in the hidden layer is the sum of the weighted component values from the input layer. An assigned transfer function uses the net input at each processing element to calculate a local output. The local output, or individual processing element output, is projected to the next layer via the desired connections and the process is again repeated until the output layer is reached.

In supervised learning, a desired output is given as part of the training pattern. The pattern error is defined as the difference between the desired output and the actual output produced by the network. The pattern error (cumulative error) is actually a summation of all the local errors produced by the elements of the hidden layers. To obtain the desired output, each element in the hidden layers must produce a local desired output. The local error is the difference between the local desired output and the local actual output.

Once the cumulative error is known, it is back propagated through the network adjusting the individual connection weights based on its share of the local error. The next pattern is presented and the process is repeated. The cumulative delta rule works in the same fashion except that the error is not back propagated through the network until all the training patterns have been submitted.

To detail the generalized delta rule, a simple illustration is shown in Figure 2 of how a simple element is affected within the hidden layer. The net input, I_j, is the sum of the inputs, X0, X1, X2, etc., multiplied by the connection weights W_{ji}.

$$I_j = \sum W_{ji} X_i \qquad (2\text{-}1)$$

A sigmoid transfer function was used for all the back propagation networks studied. The output (y_j) is given by the sigmoid function:

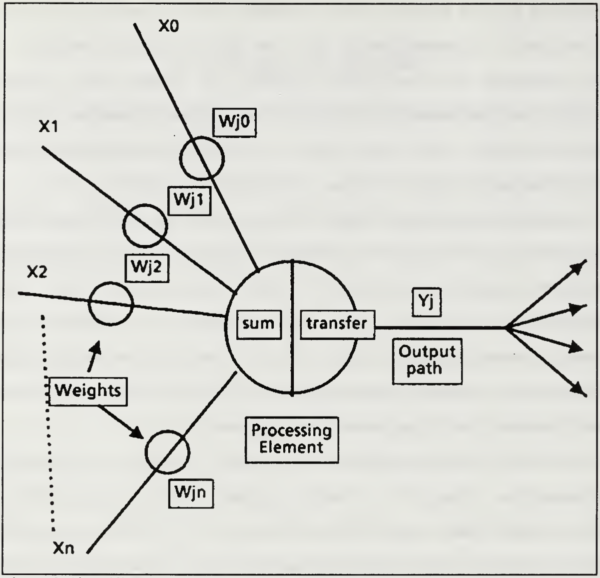

Figure 2. Simplified Element [Ref. 2]

$$y_j = (1 + e^{-Ij*Gain})^{-1} \quad (2\text{-}2)$$

The sigmoid function produces an output which is continuous over the range from zero to one. The Gain is supplied by the user and for this network was set at one for convenience.

The equation for changing weights with the generalized delta rule is given by

$$\Delta W_{ji} = \eta(t_j - y_j)I_j \quad (2\text{-}3)$$

The subscript j refers to the j^{th} element of the output layer and i refers to the i^{th} element of the input layer. Therefore, ΔW_{ij} is the weight change from the i^{th} element in the input pattern to the j^{th} element in the output pattern, I_i is the input value from the i^{th} element, t_j is the desired output, and η is a scaling factor (learning rate) used to control the rate of learning. The range of the learning rate is from zero to one. The difference $(t_j - y_j)$ is defined as the pattern error.

The weight change computed in equation 2-3 is the weight change for the network. Because it is not known where the error was generated or which elements in the hidden layers or the output layer contributed to the cumulative error, the cumulative error must be back propagated to all the elements of the hidden layers. Each element in the hidden layer is assigned a portion of the error (e_k) which is computed as

$$e_k = y' * [\sum W_{kj} * E_j] \quad (2\text{-}4)$$

The subscript k represents the hidden layer, E_j is the output error from the j^{th} element in the output layer, and y' is the derivative of the transfer function for the hidden layer with respect to the weight (W_{ji}). The local error (e_k) is applied to equation 2-3 replacing the pattern error to provide the weight change required for connections to the hidden layer element.

$$\Delta W_{ji} = \eta * e_k * I_j \qquad (2\text{-}5)$$

For the sigmoid function given in equation 2-2, the derivative of y with respect to the weights (W_{ji}) is

$$y' = y * [1 - y] \qquad (2\text{-}6)$$

The derivative ensures stability in the network by ensuring that only small to moderate error correction will be made. To illustrate, if the output value (y_j) is small (approaches zero), the difference in equation 2-6 approaches one but is multiplied by the small output value yielding an even smaller value. The value of the derivative is applied to equations 2-4 and 2-5 producing a small weight change. Because outputs are continuous over the range from zero to one, the maximum value of the derivative is 0.25 which will produce moderate weight changes to the connections. The small weight changes allow the network to approach the ideal connection weights with minimum overshoot, producing stability in the network.

The delta rule is not without problems. The small weight changes will require a large number of presentations of the training patterns to train the network. Each presentation requires two passes through the network, one forward and one backwards, increasing computation time. The back propagation network is not well suited for training in real time and the algorithm can also develop stability problems when scaled to larger networks. However, once the network has been trained, the connection weights can be locked and the network will produce outputs at a much higher speed.

The cumulative delta rule applies the same equations but instead of back propagating the error after each input pattern, the error is summed for the entire set of inputs and is then back propagated through the network. The cumulative method can lead to faster learning since it is working on the total (global) error instead of the pattern error.

B. KOHONEN LEARNING RULE

The Kohonen layer is a fairly simple process which can be considered as a "winner take all" competition. The winning element in a given layer will be the element whose weight vector is closest to the input vector. Only the winning element will produce an output and only the winner and its nearest neighbor elements are allowed to adjust their weights. Unlike a back propagation network, each element in the Kohonen layer receives inputs not only from the previous layer but also inputs from the other elements within the Kohonen layer.

Every element in the Kohonen layer calculates the dot product of its weight vector and the input vector. The largest dot product is the minimum distance between the two vectors. The activation output (dot product) is then transmitted to every other element in the layer. The activation outputs provide inhibitory inputs to most of the other elements in the Kohonen layer reducing their activation. The distance between elements has an effect on the inhibitory impact. As the distance from the affected element increases, the inhibitory effect decreases. The elements physically closest to the affected element react differently. The nearest neighbor elements provide positive inputs to the affected element. [Ref.3]

The competition within the layer continues until one element dominates and becomes the winner. The winning element is allowed to generate an output and adjust its weights. The nearest neighbors are rewarded for their positive inputs by adjusting their weights also. Thus each winning element for different patterns is a feature selection device of the input patterns.

The Kohonen layer has two requirements that must be met to ensure learning. First, the inputs to the layer must be normalized to a vector of fixed length, usually within a sphere of radius one. Furthermore, the weighting vectors must be randomly initialized to ensure competition within the layer.

The winning element and its immediate neighbors are allowed to change their weight vectors by a simple formula:

$$W_{ij(new)} = W_{ij} + n\,(X_{ij} - W_{ij}) \qquad (2\text{-}7)$$

where X_{ij} is the input vector and n is the learning rate whose values range from zero to one. The weighting vector of the winning element is rotated toward the input vector, reducing the angle between the two vectors, which increases the activation output, and reduces the minimum distance. Over time, the weighting vector will become the average of all the input vectors causing the associated element to continue winning.

C. *NESTOR DEVELOPMENT SYSTEM*

The *Nestor Development System* (NDS 500) is an adaptive pattern recognition system produced by Nestor, Incorporated of Providence, Rhode Island. Unlike *Neural Ware*, *Nestor* is self contained and the user has little control on the type of learning taking place. The user is responsible for presenting the patterns in an appropriate fashion and the **Nestor Learning System** (NLS) is designed to construct, train, and test the system and evaluate the final results.

The NLS trains the network by taking individual elements of the input pattern and treating them as features. The user defines which features will comprise the feature set. This feature set must completely describe the pattern such that the network will be able to distinguish differences between various patterns. The system uses supervised training to distinguish between patterns and variations within a classification.

The pattern features define a point (or prototype) in a feature space. As patterns are presented, influence fields around the prototypes are developed. These influence fields represent variations within a class of patterns. As training progresses, influence fields will attempt to shrink as other classes of patterns are presented. The user determines the minimum size of this influence field. Once trained, the influence field will 'fire' when an input pattern falls within its boundaries. Influence fields may overlap, and the program is designed to recognize and acknowledge when input patterns fit this category.

IV. PATTERN SET-UP AND RESULTS

A. BACK PROPAGATION METHOD

1. Pattern Set-Up

A commercially available software package produced by *NEURAL WARE, INCORPORATED* was used to develop the back propagation and back propagation/Kohonen networks. A *Sun* 386i computer was used for network processing and testing. Once successfully tested, the same networks were trained and tested on an *IBM PS2/50Z* computer with comparable results.

The cumulative back propagation method was used for two slightly different successful networks. Both networks consist of an input layer of eleven elements and two hidden layers, the first made up of nine elements, the second, seven elements. The first network was used for two analyses, a two output back propagation full data set analysis (Two Output BPFDS), and a two output back propagation reduced data set analysis (Two Output BPRDS) and is shown in Figure 3. The second network was a three output back propagation network (Three Output BP) and is shown in Figure 4. Details of the networks are given in Appendix C.

Before the successful networks were established, an initial trial network using all eighteen data points per

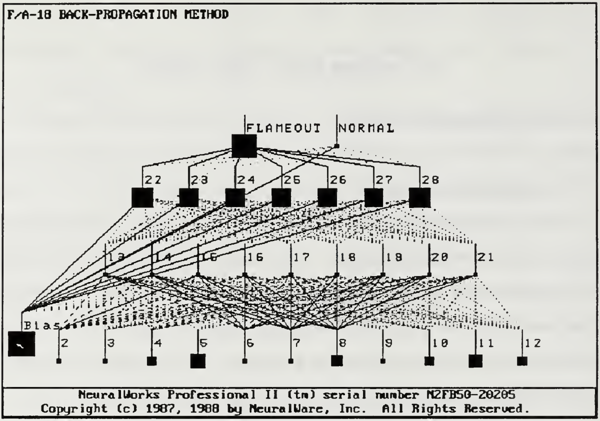

Figure 3. Two Output Back Propagation Network.

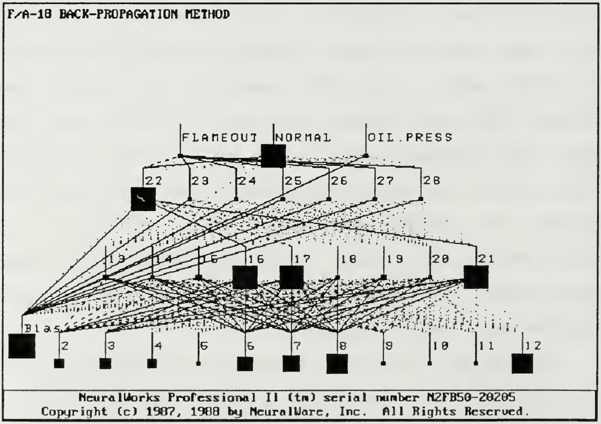

Figure 4. Three Output Back Propagation Network.

pattern was developed which included a normalized hidden layer. This initial network is shown in Figure 5. The normalized layer used a *NORMSCALE* transfer function which takes the input vector (pattern) and projects it to a unit sphere. The purpose of normalizing the data was to ensure that the network treated each component of the input pattern equally. The data ranged from -20 to 1000. The *NORMSCALE* method, however, proved inadequate. The larger values (EGT, N1, N2) dominated the normalized vector while changes in the smaller values had little or no effect on the vector. Since

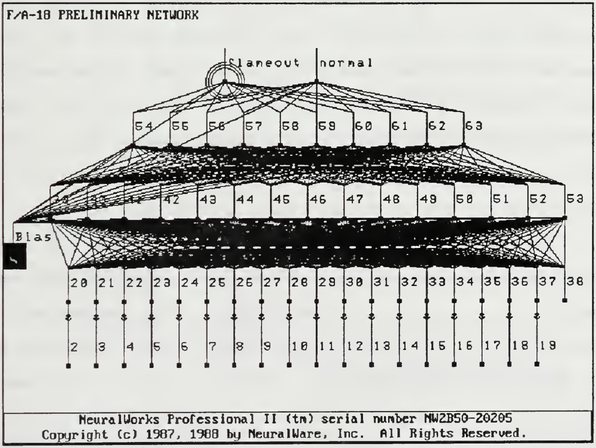

Figure 5. Initial Trail Network.

the data for the flameout was based on engine compressor problems, it was anticipated that vibration levels would help enable the system to recognize the flameout condition and possibly anticipate compressor failure. Since vibration levels were on a much smaller scale than EGT values, see Table 1, changes in vibration levels had little or no effect on the input vector in the *NORMSCALE* method.

It was decided that each individual component of the input pattern would have to be normalized to one essentially generating equal weighting for each component. An attempt was made to use the network software to accomplish the normalizing but it was not designed for individual normalizing. A FORTRAN program was written to normalize the data by dividing each component by the largest value (engine limit) for that component. The normalized data method lead to successful neural network modelling. The size of the original input pattern was also reduced by eliminating unnecessary inputs such as time, altitude, etc., which were not felt to be significant to the compressor failure problem.

Neural networks take an input vector (pattern) of a set number of components and produce an output vector in which the number of components has been reduced. The compression of pattern components occurs in the hidden layers. Inspection of the normalized data, Table 2, exhibits a grouping of about five range clusters of similar data (0 to 0.2, 0.2 to 0.4, 0.4 to 0.6, 0.6 to 0.8, and 0.8 to 1.0). To accommodate these

MSDRS FILE: 163142.089 IECMS REPORT 07-Jun-89 09:26 AM PAGE: 1
SINGLE ENGINE

AIRCRAFT TAIL NUMBER: 163142 ENGINE: R S/N: UNKNOWN

INITIATED BY: PILOT INITIATED

OPERATING CONDITIONS: WEIGHT ON WHEELS: YES APC ENGAGED: NO VCS ENGAGED: NO

BLEED AIR DOOR	N2 LOCKUP	BOOST PRESS LOW	ANTI-ICE VALVE
OPEN	NO	NO	CLOSED

PDTIME SEC	COMP: DISC: PRESS: PSIA	TURBINE: DISC: PRESS: PSIG	ENGINE: INLET: TEMP: DEG C	AC ALT FT	MACH NUMBER	ANGLE OF ATTACK: DEG	EGT DEG C	FAN: SPEED: N1: RPM	COMP: SPEED: N2: RPM	NOZ POZ PER	FUEL: FLOW: PPH	PLA: DEG	BB VIB: AVERAGE: IN/S	NL 1: REV: AVER: IN/S	NH 1: REV: AVER: IN/S	OIL: PRESS: AVER: PSIA	FIT: DEG C
*** BEGIN PRE-EVENT DATA																	
11233.25	38.	15.	28.	0.	0.10	-4.50	479.	34.	64.	76.	744.	16.					
11233.45	38.	15.	28.	0.	0.10	-4.49	479.	34.	64.	75.	736.	16.					
11233.65	38.	15.	28.	0.	0.10	-4.51	479.	34.	65.	75.	736.	16.					
11233.65	38.	15.	28.	0.	0.10	-4.51	479.	34.	65.	75.	736.	16.	0.2	0.1	0.2	63.	41.
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11236.25	39.	15.	28.	0.	0.10	-4.48	477.	34.	65.	75.	736.	16.					

Table 1 Original IECMS Report

MSDRS FILE: 162466.020 IECMS REPORT 06-Jun-89 03:46 PM PAGE: 1
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AIRCRAFT TAIL NUMBER: 162466 ENGINE: R S/N: UNKNOWN

INITIATED BY: EXCEEDANCE RECORD

OPERATING CONDITIONS: WEIGHT ON WHEELS: NO APC ENGAGED: NO VCS ENGAGED: NO

BLEED AIR DOOR	N2 LOCKUP	BOOST PRESS LOW	ANTI-ICE VALVE
OPEN	NO	NO	CLOSED

COMP: DISC: PRESS: PSIA:	TURBINE DISC PRESS PSIG	ENGINE INLET TEMP DEG C	MACH NUMBER	EGT DEG C	FAN SPEED N1 RPM	COMP SPEED N2 RPM	BB VIB: AVERAGE: N/S	NL 1 REV AVER IN/S	NH 1 REV AVER IN/S	OIL PRESS AVER PSIA
*** BEGIN PRE-EVENT DATA										
0.1194	0.2000	0.3800	0.5900	0.2680	0.4412	0.7000	0.1500	0.4000	0.5000	0.5154
*** END PRE-EVENT DATA										
*** RT ENGINE FLAMEOUT APPEARED										
0.0484	0.2000	0.3800	0.5800	0.2100	0.3235	0.5800	0.1500	0.4000	0.6000	0.4231
*** R VERTICAL STRAIN GAGE FAIL MMP CODE 605 APPEARED										
*** R ENG FLAMEOUT MMP CODE 766 APPEARED										
0.0452	0.2000	0.3800	0.5800	0.1950	0.0000	0.5500	0.1500	0.4000	0.6000	0.4231
0.0387	0.2000	0.3800	0.5800	0.1850	0.0000	0.5200	0.1500	0.4000	0.6000	0.4231
0.0387	0.1800	0.3800	0.5800	0.1770	0.0000	0.4900	0.1500	0.4000	0.5000	0.4231
0.0355	0.1800	0.3600	0.5800	0.1700	0.0000	0.4700	0.1500	0.4000	0.5000	0.4231
0.0323	0.1800	0.3600	0.5800	0.1640	0.0000	0.4500	0.1500	0.4000	0.5000	0.4231
0.0290	0.1800	0.3600	0.5800	0.1600	0.0000	0.4300	0.1250	0.4000	0.4000	0.4231
*** RT ENGINE FLAMEOUT CLEARED										
0.0290	0.1800	0.3600	0.5700	0.1550	0.0000	0.4100	0.1250	0.4000	0.4000	0.4231
0.0290	0.2000	0.3600	0.5700	0.1510	0.0000	0.3900	0.1250	0.4000	0.4000	0.4231
0.0290	0.2000	0.3600	0.5700	0.1480	0.0000	0.3700	0.1250	0.4000	0.4000	0.4231
0.0290	0.2000	0.3600	0.5700	0.1450	0.0000	0.3600	0.1250	0.4000	0.4000	0.4231
0.0258	0.2000	0.3600	0.5700	0.1420	0.0000	0.3500	0.1250	0.4000	0.4000	0.4231

Table 2. Modified Input Data

clusters of data and connections between non-clustered data points (example, compressor speed and compressor discharge pressure), nine elements were chosen for the first hidden layer. The second hidden layer consists of seven elements. Choosing too few elements for the hidden layers may hinder the learning process by not allowing the network ample connections to properly group components of the input pattern. Too many elements may slow learning. It is possible that the number of hidden elements could be reduced for the present configuration.

The two element output layer was chosen over a single output (ON/OFF set-up) to facilitate further expansion of the network as in the case of Figure 4. The set-up of the output layer simulates the caution panel found in the cockpit of the aircraft. When a mechanical problem occurs, a sensor in the engine lights the appropriate caution light on the pilot's dash. When the network 'senses' a problem, it lights the appropriate block in the output layer (caution panel).

Data used for both networks was real world data supplied by Naval Air Depot, North Island [Appendix A] with the exception of the low oil pressure data. The low oil pressure data was created from normal operating engine data with the average oil pressure arbitrarily lowered. The data was manipulated to fulfill a need to further expand the network.

2. Two Output Back Propagation/ Full Data Set

The first investigation analyzed was a two output network which was trained on all available data. After training for 10,000 presentations of the training patterns, the network was tested against the training patterns. Of the 1755 patterns presented, the network could not properly identify about 200 patterns. Inspection of the faulty patterns revealed that the network had correctly identified the patterns but the patterns had been mislabeled. Because actual aircraft data was used, several areas of certain data patterns were poorly defined as normal operating range and failure criteria. In several instances, data for a normal condition indicated that there was no RPM for the compressor or turbine or both. Since the network was not trained to recognize gage failures, these patterns were discarded and the network retrained. Subsequent training and testing with correctly labeled data and removal of anomalous patterns produced 100% correct response from the network on all the data available.

The final version of the network was trained for 6,000 presentations. The amount of training required was determined by the magnitude of the cumulative error at the output. Figure 6 is a graph of the cumulative error per presentation for the Two Output BPFDS. The error is exponentially approaching zero as expected. Training was stopped at six thousand presentations since improvements to the network with further training would be minimal. The graph indicates that if

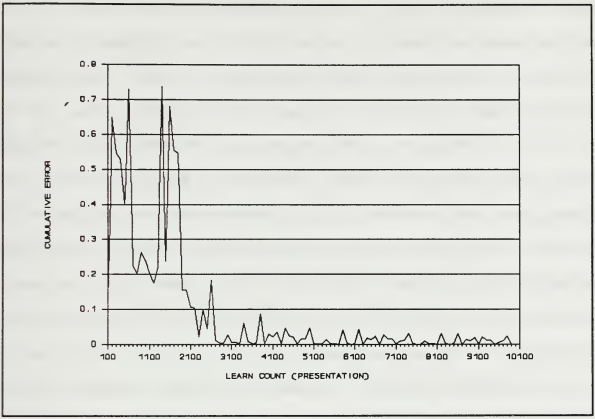

Figure 6. Two Output BPFDS Cumulative Output Error.

training continued, the error would decrease further but the time to train would improve substantially.

Each element of the output layer will produce an output value when a pattern is submitted to the network. The desired output for the flameout condition in a two output network is one for the flameout element and zero for the normal element. Figure 3 is a representation of the flameout condition. The size of the element block is representative of the output value for the element. A large block indicates an output value of one. The small block indicates an output value of zero. As the output value varies between zero and one, the size of the box changes in proportion to the output value. For a desired normal condition, the flameout element value should be zero and the normal element value should be one. Unless the network is trained until the cumulative error is zero, the outputs during testing will not necessarily be exactly zero and one but the difference will be small for low cumulative errors. Even if trained until the cumulative error is zero, the network may not produce outputs of exactly one and zero for patterns which the networks were not trained on. The larger of the output elements is the output choice of the neural network for the given input pattern. This output choice will be called the dominant element.

A dominant element may be the correct response for a given input pattern but has a low output value with respect to a desired output of one. The network will have a low confidence level in its choice of the dominant element due to the low output value. For example, an input pattern generates an output value for the dominant element of 0.52. The remaining element's value is 0.48. Although the dominant element is the correct response, the network indicates (through its weight connections and algorithm) that the dominant element is only slightly (four percentage points) better as the correct response than the remaining element. In this case, the network is not confident of its response. As the output values approach one, the network's confidence level increases.

For the Two Output BPFDS network, the cumulative error value was small (0.04) after training. The network was able to recognize the patterns correctly with an output value of .96 or better which is a high confidence level for the network. Thus further training was unwarranted.

3. The Two Output Back Propagation/ Reduced Data Set

Inspection of the Two Output BPFDS network indicated that many of the patterns presented to the network were essentially the same type. Therefore, the training file was reduced to 186 arbitrarily chosen patterns. The training patterns came from 31 files and the desired outputs were evenly divided between the flameout condition and the normal operating condition. The Two Output BPRDS network was trained for 22,000 presentations in order to reduce the error to a stable value. Figure 7 presents the cumulative error per presentation.

The Two Output BPRDS network produced similar results to those of the Two Output BPFDS. The network was first tested against the training patterns with a correct response given every time. The network was then presented all the data available and again returned 100% correct responses with a output of .90 or better. These results are a perfect example of how a neural network works. The network is trained on a limited number of patterns but will give correct responses on previously unseen similar patterns with a high degree of accuracy.

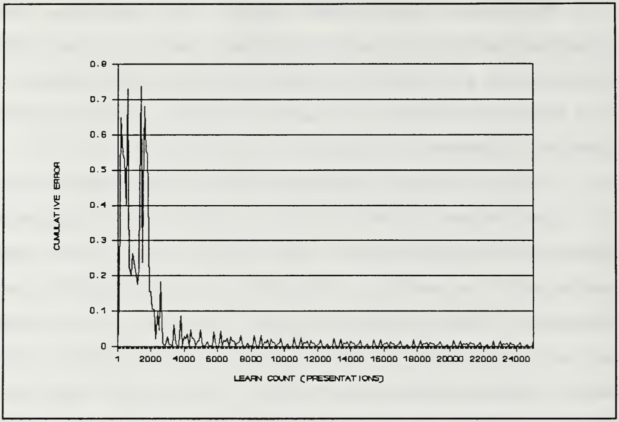

Figure 7. Run Two Cumulative Output Error.

4. The Three Output Back Propagation Network

The Three Output BP network was a further expansion of the first two runs. This time, the network was trained to produce one of three outputs. The network was trained for 20,000 presentations, see Figure 8. The network was again tested against the training pattern and against other data held in reserve. The three output network responded correctly 100% of the time with an output value of .90 or higher.

The two and three output networks displayed some results which may aid in further designs of networks using the back propagation method. Figure 3 shows the weights (size) of the elements in the hidden layer from an earlier run of a two

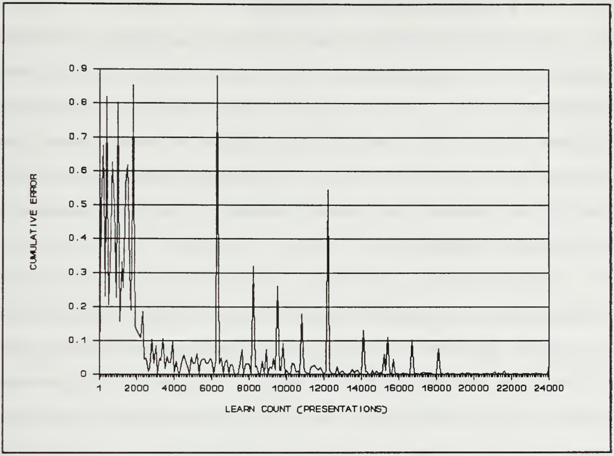

Figure 8. Run Three Cumulative Output Error.

output network. It was noted that each response dominates a layer, the normal condition generated large values in the first hidden layer while the flameout condition generated large values in the second hidden layer. The domination of a layer is to be expected because of feature extraction and only two outputs. The three output network produces similar results for two of the outputs (flameout and low oil pressure) while the third output (normal condition) shares both layers (Figure 4). The current network should be able to support several additional outputs but this will require added training to further segment the hidden elements.

5. Pre-Event Data Evaluation

The F/A-18 IECMS system records data up to ten seconds prior to a recorded event. Ten seconds worth of data are temporarily stored on a computer chip which is continuously updated until a major event occurs. When an event occurs, the data on the chip is dumped to a magnetic tape along with the data after the event. This ten seconds of data is referred to as pre-event data.

From all the data obtained, pre-event data for the engine flameout condition was extremely limited and consisted of only 22 patterns. The range of the pre-event data was from one to five seconds prior to engine flameout. The pre-event data was scattered among all the files with only one series (one to five seconds) of patterns coming from a single file.

It is anticipated that not all failures will be predicable. Failure can be attributed to metal fatigue which may occur suddenly without affecting engine performance. The neural network is designed to recognize deterioration of engine performance and vibration levels and to predict failure based on the reduced performance.

The pre-event data patterns consisted of five patterns in the five second prior to failure range, four patterns in the four second prior to failure range, three patterns in the three second prior to failure range, three patterns in the two second prior to failure range, and seven patterns in the one second prior to failure range. These patterns were presented to each of the networks and the percentage of correct responses (failure predictions) for each pre-event time are shown in Figure 9 for each of the back propagation networks.

For the two to four second range all of the networks were able to predict failure. All the networks for the one and five second range produced poor result. Because of the scatter of the patterns, no firm statements can be made as to the validity of the network in predicting failure. Most of the data files contained only one or two pre-event patterns. To fully analyze the network, numerous patterns in decreasing time increments are required as far in advance as possible. These patterns must be a series from a single engine for a particular failure event. Any trends that develop from these new patterns can be readily studied and determinations made

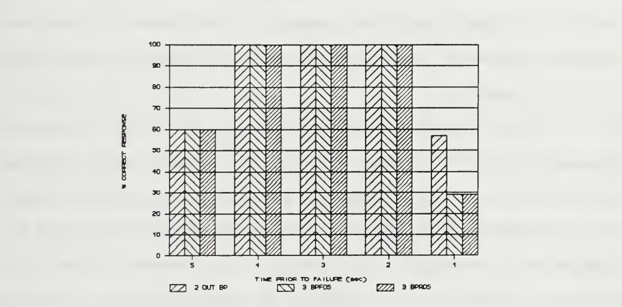

Figure 9. Pre-Event Pattern Results For Back Propagation Network.

as to how far in advance predictions by the network can be made. These patterns will require additional data acquisition with pre-event data being temporarily stored for one or two minutes vice the current ten seconds. A suitable amount of data could be collected very easily.

All the back propagation networks were able to predict failure to some degree with the Two Output BPFDS network (R1) generating slightly better results than the rest. The other two networks may need more patterns to train on or the networks may require more training to produce better results.

B. BACK PROPAGATION/KOHONEN METHOD

1. Kohonen Two Output Network

A two output back propagation network with a Kohonen layer was developed and is shown in Figure 10. Details of the network are given in Appendix C. The Kohonen layer consists of fourteen elements. If too few elements are used, some desired outputs may get ignored. The same network was attempted with as few as four elements in the Kohonen layer with poor results.

The network was trained for six thousand presentations, see Figure 11. It is evident that once the network was settled, there were virtually no more changes made. The network was trained with the same pattern as the Two Output BPRDS network. The network was tested against all possible patterns (1755 total) and recognized all but six

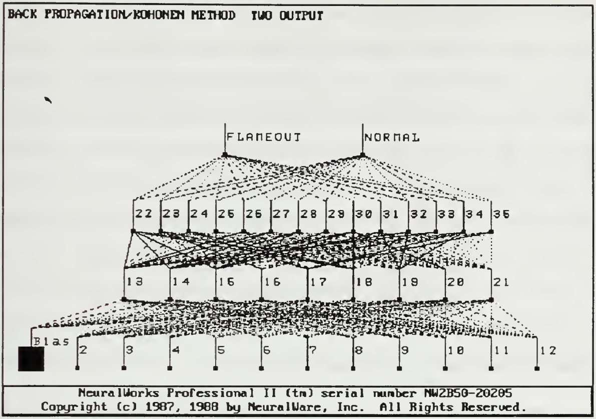

Figure 10. Kohonen Two Output Network

patterns for a 99% correct response rate.

The six patterns that the network was unable to recognize were actually two sets of patterns from two different files. The patterns are the first three patterns for each file and in both cases, it is obvious from the data that the engine is winding down after flameout. Although flameout has occurred in both cases, the network recognizes the conditions as normal. The pattern components for turbine and compressor speeds and pressures are within the normal range for a slower RPM of the engine and the vibration levels are low. The network did not recognize that the engine quit because it had no means to determine the difference between

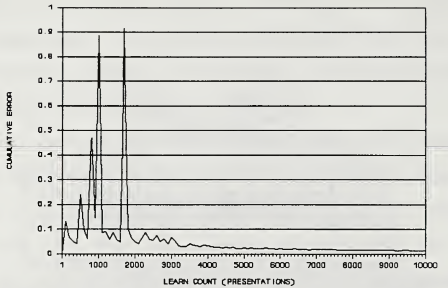

Figure 11. Error Analysis of 14 Element Kohonen Layer.

a low RPM engine and a flameout condition. Additional inputs may help distinguish between an engine failure and an engine at low RPM.

2. Kohonen Three Output Network

Two back propagation/Kohonen networks were investigated. The input layer and the first hidden layer for both networks were the same as the first two layers of the Kohonen two output network. The first three output network investigated consisted of a sixteen element Kohonen layer while the second network contained an eighteen element Kohonen layer. The three output eighteen element back propagation/Kohonen network (Three output 18BPK) is shown in Figure 12.

Both three output networks were trained on the same patterns used for the Three Output BP network and tested against all available patterns. The three output sixteen element back propagation/Kohonen network (Three Output 16BPK) produced the best results with a 99% correct response after training for 15,000 presentations. The network was unable to recognize the same six patterns as the Kohonen two output network. The Three Output 16BPK network was also unable to distinguish the initial difference between a slow running engine and the flameout condition for the given components of the input pattern.

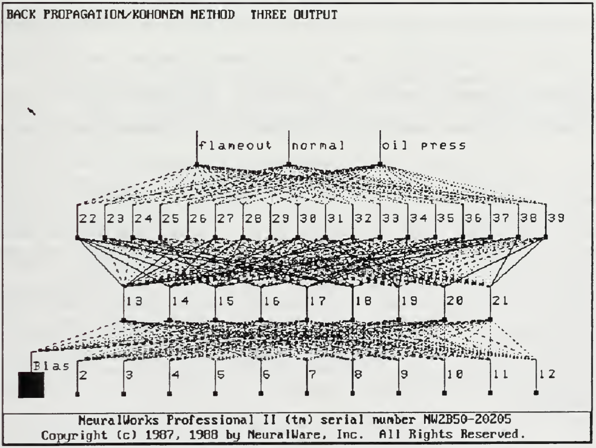

Figure 12. Three Output Kohonen Network.

During the investigation of the Three Output 16BPK network an interesting known feature of Kohonen networks appeared. An initial sixteen element Kohonen network was trained and tested with poor results. The network was unable to recognize the low oil pressure condition. To further investigate the sixteen element network, a new sixteen element Kohonen network was generated which was exactly the same as the first with the exception of the randomized weights. The second network (Three Output 16BPK) was highly successful. The randomizing of the connection weights are a major factor in the design of Kohonen layers.

The Three Output 18BPK network was developed in an attempt to decrease the required training time of the sixteen element Kohonen network. However, the eighteen element network was not as successful as the sixteen element network. The eighteen element network misjudged 102 patterns for a 95% correct response rate after training for 10,000 presentations.

The network had problems distinguishing between the normal condition and the low oil pressure condition. Eighty normal patterns were misjudged as oil pressure problems while twenty-two oil pressure conditions were misjudged as normal conditions. Increasing the amount of training may improve the percentage of correct responses but this will defeat the original purpose of the network to reduce the amount of training.

All of the Kohonen networks were tested with the pre-event data and the results are shown in Figure 13. Both the Three Output 16BPK and 18BPK networks performed well recognizing twenty out of twenty-two pre-event patterns as potential failures. Both of the three output networks missed the prediction on the same three one second pre-event patterns. The two output network failed to predict nine patterns as potential failures. As with the back propagation networks, the Kohonen networks would not be expected to predict every failure. Even though a majority of the patterns were correctly identified, there are too few pre-event patterns to make any sound predictions on the capability of the networks for prediction purposes.

C. NESTOR

> "An Encoding Unit consists of software modules that encode pattern data to produce a feature vector, the feature space associated with this representation, and the set of prototypes committed within the feature space" [Ref. 4].

Four different encoding units were used with the F/A-18 patterns and can be found in Appendix D. The encoding unit ONE_THR (encoding scheme 1) was designed to present each component of the normalized input pattern multiplied by a scaler as a feature to the network. The encoding unit SUM_CODE (encoding scheme 2) summed eight of the input pattern components to form a single feature. The eight components were compressor and turbine discharge pressures, engine inlet

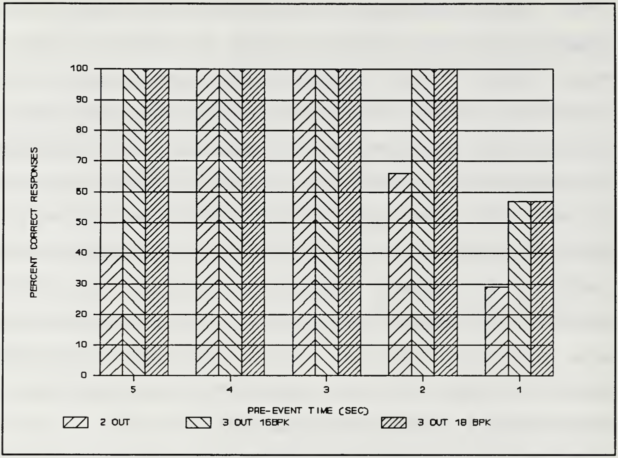

Figure 13. Results of Pre-Event Data on Kohonen Layer.

temperature, exhaust gas temperature (EGT), compressor speed, and the three vibration inputs. SUM1CODE (encoding scheme 3) summed different components of the input patterns to produce four features. The first feature combined turbine discharge pressure with the fan speed. The second feature combines the compressor discharge feature with the compressor speed. The third feature consists of the EGT only while the fourth feature summed the three vibration inputs. All of these inputs were considered critical in recognizing the engine flameout condition. The fourth encoding scheme (ONE_THR1) used four compressor related components of the input pattern to produce four features. The four components chosen were compressor discharge pressure, EGT, compressor speed, and the average vibrations.

The **NDS 500** software allows for only a single unit system, or only one encoding unit per network run. Some advantages of the single encoding unit system include quick execution and ease of assembly. However, the disadvantages include slow learning and large overlapping of influence fields.

All of the encoding schemes were trained and tested on the same patterns. The results from the four runs are shown in Figures 13 and 14. Each of the results are categorized into three groups; identified, uncertain, and unidentified. Two of the groups, identified and uncertain, are further sub-divided into correct and incorrect. If the feature values of an input pattern fall within the proper class region (prototype) of the feature space, then an identified response is given. If the feature values fall within a wrong class region, then a response of identified incorrect is generated. When a feature value falls within an overlapping class region an uncertain response is given. A correct or incorrect uncertain response depends on whether the overlapping boundary contains the correct class region. Should the feature value fail to fall within any class region,then the system responds with unidentified.

The results from RUN1PAT1 (ONE_THR) indicate that only 13.8% of the testing patterns were correctly identified. The remaining responses fall into the uncertain category indicating a large number of overlapping regions (nine out of eighteen prototypes). The manufacturer indicates that the *NESTOR* system does not handle noisy data very well and this may be the reason for the poor results.

The results of the second run, RUN2PAT1 (SUM_CODE), are improved over RUN1PAT1 (69.6% correctly identified) but still contain a large percentage (19.2%) of overlapping regions. The number of unidentified responses may be reduced by increasing the maximum influence field which was set at the default value of 37%. The number of overlapping regions is still relatively high producing 18% uncertain responses. Small input values (feature values) produce numerous overlapping regions. Because the input values were normalized to one, the system has trouble separating feature values. This is true for all the remaining cases investigated.

The third encoding scheme (RUN3PAT1) produced only 39.6% correctly identified responses. As in the first encoding scheme, the large percentage of overlapping class regions (42.8%) resulted in 60% uncertain responses. The fourth encoding scheme (RUN4PAT1) did not produce any separate (exclusive) class regions. Therefore, only uncertain responses were generated.

As shown in Figures 13 and 14 the network was unable to recognize the test patterns with any degree of accuracy. The percentage of overlapping prototypes played an important role in the number of correctly identified patterns.

Because the preliminary results from *Neural Ware* were much better and more promising, *NESTOR* was abandoned to pursue the other networks. However, encoding schemes SUM_CODE and SUM1CODE demonstrated the best potential for improvement. Experimentation with the minimum and maximum influence fields may improve results. It is also possible that unscaled data might also produce good results. The multi unit software, which allows multiple encoding units, may be required due to the noisy training patterns.

NDS(tm): Evaluate NLS Recognition Results

Results File: run1pat1.tst

General Results Summary

Patterns: Total = 101 Processed = 101

Identified		Uncertain		Unidentified
Correct	Incorrect	Correct	Incorrect	
14	0	46	41	0
13.8%	0.0%	45.5%	40.5%	0.0%

Prototypes: Exclusive = 8 47.0%
Overlapping = 9 52.9%
Total = 17

NDS(tm): Evaluate NLS Recognition Results

Results File: run2pat1.tst

General Results Summary

Patterns: Total = 99 Processed = 99

Identified		Uncertain		Unidentified
Correct	Incorrect	Correct	Incorrect	
69	0	10	8	12
69.6%	0.0%	10.1%	8.0%	12.1%

Prototypes: Exclusive = 42 80.7%
Overlapping = 10 19.2%
Total = 52

Figure 13. Results of ONE_THR and SUM_CODE NETWORKS.

NDS(tm): Evaluate NLS Recognition Results

Results File: run3pat1.tst

General Results Summary

Patterns: Total = 101 Processed = 101

Identified		Uncertain		Unidentified
Correct	Incorrect	Correct	Incorrect	
40	0	39	22	0
39.6%	0.0%	38.6%	21.7%	0.0%

Prototypes: Exclusive = 4 57.1%
Overlapping = 3 42.8%
Total = 7

NDS(tm): Evaluate NLS Recognition Results

Results File: run4pat1.tst

General Results Summary

Patterns: Total = 101 Processed = 101

Identified		Uncertain		Unidentified
Correct	Incorrect	Correct	Incorrect	
0	0	42	59	0
0.0%	0.0%	41.5%	58.4%	0.0%

Prototypes: Exclusive = 0 0.0%
Overlapping = 2 100.0%
Total = 2

Figure 14. Results of SUM1CODE and ONE_THR1 Networks.

V. CONCLUSIONS

Although a limited study, neural networks have shown the potential for successful identification of input patterns for the F/A-18 engine or any engine with a monitoring system onboard.

The most effective network studied was the back propagation network. An expansion of the number of outputs to coincide with the IECMS outputs is required. The expansion should be approached by adding several outputs to the basic network demonstrated in this paper. Added layers and elements will be required, and if outputs are added several at a time, trends can be established to assist in building the larger networks.

The back propagation and back propagation/Kohonen networks have shown the ability to predict failures. However, the failure must be predictable far enough in advance to enable a control system or pilot to act effectively to prevent catastrophic failure. To predict failure far enough in advance for the pilot to react, would require a minimum of thirty seconds advance notice. Thirty seconds would allow the pilot sufficient time to recognize the warning, check for possible secondary indications, and decide what, if any, actions will be taken. Five seconds in advance, as tested in the study, would not allow a pilot or even a control system time to verify the condition and react to prevent the failure. Therefore, to fully test the network, one minute of pre-event engine data is required.This data could be easily obtained by switching the microchip in the aircraft's ECAM system. The new microchip would need to be able to record at least one minute's worth of data vice the ten seconds currently recorded. Some minor software changes may also be required. The necessary data for the compressor problem and possibly other problems would be easily obtained with no change to the current ground system.

Neural networks could become more effective with the addition of better sensors. In the situation of the F/A-18 compressor failure, prediction of the failure could improve with more vibration sensors in the compressor area. Due to the high speeds of today's turbine engines, vibration analysis would be the best means of monitoring the engine for compressor failure. More sensors require more computer memory and also add weight to already weight conscious aircraft. The addition of sensors may provide the networks the capability to predict potential problems far enough in advance to prevent catastrophic failure.

A second network would be required to verify the results of the first and to provide a back-up system. Although several networks were tested in the study, there are many more available algorithms which may prove more effective than the Back Propagation/Kohonen method. The necessity for the second network is as important as the first because of the requirement for redundant systems on all Navy aircraft and the need for verification of a potential problem.

Application of neural networks to engine condition monitoring systems is feasible and with faster computers being developed every year, they are practical. However, their acceptance is dependant on their ability to predict potential problems with a high degree of accuracy. Neural networks are practical in that they can be easily trained at a base station prior to installation in the aircraft's computer reducing the amount of required computer memory. As new data is acquired, the networks can be easily updated in a short amount of time. However, replacing today's simple and reliable system of monitoring specified values for minimum and maximums will require proven performance in test cells and numerous studies. The user must be convinced of the networks practicality.

The potential of neural networks in engine condition monitoring systems warrants further studies.

APPENDIX A. DATA ACQUISITION

Data for this project was obtained from the F/A-18 Engine Condition and Monitoring System (ECAMS) branch of the Naval Aviation Depot, Naval Air Station North Island, San Diego, California. The ECAMS branch contains an archive section which maintains through Martin Marietta, a contractor, records of all ECAMS raw data sent from the fleet squadrons.

Several problem areas were encountered while attempting to obtain this data. In early conversations with personnel from Light Attack Wing One (CLAW 1) it became obvious that several publications were required to relate required data with what was actually available from the squadrons or archives. The *F/A-18 Enhanced Comprehensive Asset Management System (ECAMS) Program Guide*, *F-18 Report User's Guide (ECAMS)* (RUG), and *The Operations Instructions, Technical Manual* (SUM), took over two months to acquire from the Naval Aviation Depot, North Island. The RUG proved to be the most appropriate manual. It fully describes the various reports generated by the ECAMS processing unit. The reports are grouped together into work packages in the manual which also contains sample reports. The work packages are grouped as follows:

a) Flight Information and Tactical Data Reports

b) Inflight Engine Condition Monitoring System (IECMS) Reports

c) Engine-Parts Life Tracking Systems Report

d) Avionics Built-In-Test Recording Reports

e) Aircraft Structural Strain Monitoring Reports

f) Fuel/Recorder Message Reports

This paper dealt with data from the IECMS Reports, primarily the Single Engine IECMS Reports.

Once the manuals were received and studied, arrangements were made to visit a squadron at Naval Air Station, Lemoore, California to obtain data. Upon arrival, AQ2 Bernard of VFA-125 proceeded to explain exactly how the system worked and produced all requested reports. Generation of the reports was found to be time consuming and the archives were explained. With copies of the various reports in hand via hard copies and one-half inch magnetic tape, it was now easy to determine exactly what was required. Mr Curtis Kimbal (Autovon 735-9455) of the IECMS Archives was contacted to obtain the required data. It was learned that data was listed only by aircraft side number and date and that there was no cross reference for various engine problems. The Aviation Safety School in Monterey, California provided the necessary accident reports for compressor problems for the past three years.

Once the required dates and side numbers were obtained and passed to the archives, there were several delays in receiving the data. To date no one had requested more than two flights worth of data. The 29 requested flights of data presented several problems to the contractor. The archiving contract required payment to the contractor to retrieve data. This bill was payed by the archives division. Of the requested flights and dates several files of data were missing. The contractor sent the closest data to the requested date in these cases which caused some confusion due to the lack of explanation by the contractor. After investigating the reason for the submission of the non-requested data, it was assumed that in some cases the data was not submitted to the archives because it had been acquired by the Accident Investigation Board or was destroyed with the aircraft. The contractor did his best to fulfill the request.

The data received was raw data and had to be processed on an EICMS Processing Unit. After contacting several squadrons, both active and reserve, a clear problem existed in processing the data. The squadrons were willing to help on an as available basis, which was unacceptable for the amount of data obtained. After further conversations with the archives division, it was determined that the IECMS Branch had two processing units, one of which would be made available on a full time basis. A week was spent at the EICMS Branch processing the data.

While at the EICMS Branch, it was learned that the archives are scheduled to be moved from the contractor to the

EICMS Archive Branch at NAS North Island in the Fall of 1989. This should make acquisition of the data easier and faster.

APPENDIX B. FORTRAN PROGRAMS

A. CONV1.FORTRAN

Program CONV1.FORTRAN was designed to take the processed data supplied by the IECMS archive Branch and put it into a workable IBM mainframe computer format. A file of the supplied data consisted of one record of length 14 bytes and a varying number of records with a length of 512 bytes. The half inch nine track tapes with the processed data were read by the IBM mainframe using standard procedures provided by the Computer Center of the Naval Postgraduate School. Because of the varying length of the records, the first record of each file was ignored. The first record was believed to be the file name and the lack of this record did not affect the print out of the file. The remaining records were copied in files to the user's A disk on the mainframe computer. CONV1.FORTRAN was then applied to reduce the records to a length of 132 bytes. Several codes in the processed data were unrecognizable by the IBM mainframe computer but this fortran program converts the codes to those codes recognized by the mainframe computer.

```
C     ************************************************************************
C     ************************************************************************
C
                                    CONV1.FORTRAN

      ************************************************************************
      ************************************************************************

C     THIS PROGRAM IS DESIGNED TO TAKE F-18 DATA FROM THE MVS SYSTEM
C     AND CONVERT THE 512 BYTE RECORD INTO A 132 BYTE RECORD. THIS DATA
C     CAN THE BE DOWN-LOADED TO A PC. 'HEX', 'CR1','CR2','POP','PIP',
C     ARE USED TO CHECK FOR EXTRANEOUS HEXIDECIMAL CODES WHICH SHOW UP
C     IN THE ROUGH DATA AS " AND INDICATE SOME SORT OF SPACING AND
C     CARRIAGE RETURN. THIS PROGRAM WILL REMOVE THE EXTRA SPACES CAUSED
C     BY THESE CODES AND PLACES CARRIAGE RETURNS APPROPRIATELY.
C
C
C ************************************************************************
      INTEGER K,LIT,REC,M,N,P,Q,LOT,NEW,BETA
      CHARACTER*1 A(512),HEX,B(1024),CR1,CR2,POP,PIP,C(1024),D(1024)
      CHARACTER*20 FNFT,INPUT,ANS*1
      DATA HEX/Z00/,CR1/Z0D/,CR2/Z25/
      DATA POP/Z50/,PIP/Z6C/
10    BETA = 1
      PRINT *,'INPUT NAME AND FILE TYPE OF FILE TO BE READ'
      READ '(A)',INPUT
      PRINT *, ' INPUT NAME OF DESIRED OUTPUT FILE AND FILE TYPE'
      READ '(A)', FNFT
      PRINT *,'INPUT THE NUMBER OF RECORDS IN THE FILE TO BE READ'
      READ *,REC
      OPEN (UNIT=2, FILE = FNFT,STATUS='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT=1, FILE= INPUT)
      LIT = 1
      LOT = 0

C*******************************************************************
C     LIT IS THE COUNTER FOR THE RECORD NUMBER FOR PRINTING
C*******************************************************************
C   THIS IS THE INITIAL READING OF THE ROUGH DATA
C*******************************************************************
      DO 2000  M=1,REC
      DATA (B(I),I=1,512) /512*' '/
      READ (1,'(512A1)', END=20) A
20    P=1
C*******************************************************************
C     THIS LOOP ELIMINATES THE EXTRA SPACES IN THE PROGRAM
C     CAUSED BY THE HEX CODE 00 WHICH THE IBM DOES NOT RECOGNIZE.
C*******************************************************************
        DATA (D(N),N=1,1024) /1024*' '/
        IF (LOT .EQ. 0) GO TO 150
C           PRINT*,'K=',K,'LOT=',LOT,'REC=',M
        DO 100 N = 1, LOT
        D(N) = C(K)
        K = K + 1
100     CONTINUE
150       DO 125 N = (LOT +1),(512 + LOT)
          D(N) = A(N- LOT)
125       CONTINUE
      DO 500 N =1,(512+LOT)
      IF (D(N) .EQ. HEX) GO TO 500
      B(P) = D(N)
      P = P+1
```

```
500   CONTINUE
      K=1
C*****************************************************************
C     THIS LOOP AND THE NEXT SET UP THE CARRIAGE RETURN THAT
C     THE IBM DOES NOT RECOGNIZE (0D25).
C***************************************************************
      DO 600 I=2,(P-1)
      IF (B(I-1) .EQ. CR1 .AND. B(I) .EQ. CR2) B(I)=POP
      IF (B(I-1) .EQ.CR1) B(I-1)=PIP
600   CONTINUE
      Q = 1
        NEW = 512 + LOT
      DATA (C(I),I=1,1024) /1024*' '/
      DO 700 N=1,P-1
      IF (B(N) .EQ. PIP) GO TO 700
      C(Q)=B(N)
      Q = Q+1
700   CONTINUE
C**************************************************************************
C     THIS LOOP ACTUALLY DOES THE CARRIAGE RETURN AND WRITES THE DATA
C     TO THE SPECIFIED FILE (UNIT 2).
C**************************************************************************
      DO 1000 I=1,Q-1
      IF (C(I) .EQ. POP) THEN
      C(I)=' '
      WRITE(2,30,REC=LIT) (C(J),J=K,I)
30    FORMAT(131A1)
      LIT = LIT + 1
        LOT = (Q-1)-I
      K = I+1
      END IF
C     IF (I .EQ.Q-1) THEN
C     WRITE(2,30,REC=LIT) (C(J),J=K,Q-1)
C     LIT = LIT +1
C     END IF
1000  CONTINUE
2000  CONTINUE
      PRINT *,'DO YOU WANT ANOTHER RUN? (Y OR N)'
      READ '(A)',ANS
C     IF (ANS .EQ. 'Y') THEN
      GO TO 10
C     END IF
3000  END
```

B. CONV2.FORTRAN

CONV2.FORTRAN reduced the processed data to record lengths of 132 bytes. CONV2.FORTRAN applies the proper line breaks for the various IECMS reports and alignsthe data in proper columns. The type of report must be known prior to running CONV2.FORTRAN.

```
******************************************************************************
******************************************************************************

                                   CONV2.FORTRAN

******************************************************************************
******************************************************************************
C
C  THIS PROGRAM TAKES THE RESULTS OF CONV1.FOR AND PUTS THE DATA INTO
C  THE PROPER IECMS FORMAT FOR THE SPECIFIC TYPE OF REPORT.
C
******************************************************************************

      INTEGER LIT,LIT1,LT2,I,K
      CHARACTER*20 INPUT,OUTPUT,ANS*1
      CHARACTER*27 T1,T2,T3,T4,T5,T6,T7
10    CALL EXCMS ('CLRSCRN')
        PRINT *,'THIS PROGRAM WILL HANDLE THE FOLLOWING TYPES OF FILES'
        PRINT *
      T1='1. IECMS DUAL ENGINE REPORT'
      T2='2. IECMS SINGLE ENGINE REPORT'
      T3='3. CODE 31, LIFE CYCLE DATA'
      T4='4. CODE 32, PRE-EVENT DATA'
      T5='5. CODE 34, PRE-EVENT DATA'
      T6='6. CODE 35, POST-EVENT DATA'
      T7='7. CODE 36, POST-EVENT DATA'
        PRINT 20,T1,T5
20    FORMAT (A27,T40,A27)
        PRINT *
        PRINT 20,T2,T6
        PRINT *
        PRINT 20,T3,T7
        PRINT *
        PRINT *,T4
        PRINT *
      PRINT *,'INPUT FILE NAME AND FILE TYPE:'
      READ '(A)',INPUT
      PRINT *,'DESIRED OUPUT FILE NAME:'
      READ '(A)',OUTPUT
      PRINT *,'INPUT THE NUMBER OF RECORDS OF THE DESIRED FILE:'
      READ *,LIT1
      PRINT *,'INPUT TYPE REPORT NUMBER (1,2,3,4,5,6,7):'
      READ *,LT1
        IF (LT1 .EQ. 1) GO TO 200
        IF (LT1 .EQ. 2) GO TO 150
```

```
        IF (LT1 .EQ. 3) CALL CODE31 (INPUT,OUTPUT,LIT1)
        IF (LT1 .EQ. 4 .OR. LT1 .EQ. 6) GO TO 210
         IF (LT1 .EQ. 5) CALL CODE34(INPUT,OUTPUT, LIT1)
         IF (LT1 .EQ. 7) CALL CODE36 (INPUT, OUTPUT, LIT1)
         GO TO 300
150      CALL ICMSE(INPUT,LIT1,LT2)
         CALL FINAL1(OUTPUT,LT2)
         GO TO 300
200    CALL ALIGN(INPUT,LIT1,LT2)
       CALL FINAL (OUTPUT,LT2)
       GO TO 300
210     IF (LT1 .EQ. 4) LT6 = 14
        IF (LT1 .EQ. 6) LT6 = 11
        CALL CODE32 (INPUT,OUTPUT,LIT1)
        GO TO 300
300      PRINT *,'DO YOU WANT TO MAKE ANOTHER RUN? (Y OR N)'
         READ '(A)', ANS
         IF (ANS .EQ. 'Y') GO TO 10
       END
C ***************************************************************************

C
      SUBROUTINE ALIGN (INPUT,LIT1,LT2)
      INTEGER LIT,LIT1,LT2,I,K
      CHARACTER*9 A1,B1,A2*44,A3*56,A4*22,B2*44,B3*56,B4*22
      CHARACTER*131 TITLE,BLANK2*44, BLANK3*56,INPUT*20,NOTE*9
      OPEN (UNIT=1, FILE= INPUT,STATUS='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT =4, STATUS ='SCRATCH',ACCESS='DIRECT',
     * FORM='FORMATTED', RECL=132)

      LT2 = 1
      LT3 = 1
      DO 2500 I = 1, 21
      READ (1,'(1A130)',REC=LT3) TITLE
2001  WRITE(4,2005,REC=LT2)  TITLE
2005   FORMAT (A130)
      LT2 = LT2 + 1
2490  LT3 = LT3 + 1
2500  CONTINUE
      READ (1,2050,REC=LT3) A1,A2,A3,A4
2050  FORMAT (1A9,1A44,1A56,1A22)
      LT3 = LT3 + 1
      DO 2600 I = 1, (LIT1 - 21)
      READ (1,2050,REC=LT3,ERR=2600) B1,B2,B3,B4
      BLANK2 = '                                            '
      LT3 = LT3 + 1
      BLANK3='                                                        '
      NOTE = '***      '
      IF (A1 .EQ. B1) GO TO 2130
       GO TO 2065
2130  IF (A2 .EQ. BLANK2 .AND. A3 .EQ. BLANK3) THEN
        B4 = A4
        GO TO 2065
        END IF
      IF (B2 .EQ. BLANK2 .AND. B3 .EQ. BLANK3) THEN
        B2 = A2
        B3 = A3
        GO TO 2065
        END IF
      IF (A2 .EQ.BLANK2) B3 = A3
      IF (A3 .EQ. BLANK3) B2 = A2
2065  A1 = B1
      A2 = B2
```

```
      A3 = B3
      A4 = B4
      IF (A1 .EQ. NOTE) GO TO 2070
      IF (A2 .EQ. BLANK2 .OR. A3 .EQ. BLANK3) GO TO 2600
2070  WRITE (4,35, REC = LT2) A1, A2, A3, A4
35    FORMAT (1A9, 1A44, 1A56, 1A22)
      LT2 = LT2 + 1
2600  CONTINUE
      END


C
C*******************************************************************************
C SUBROUTINE FINAL      FOR IECMS DUAL ENGINE REPORT
C***************************************************************************
C
      SUBROUTINE FINAL(OUTPUT,LT2)
      INTEGER LT3,LIT1,K,I,I2,Z,LT2,LT4
      CHARACTER*131 TITLE,REM*3,REM1*3,D1*3,D2*128,S1*1,D3*109
      CHARACTER*20 OUTPUT
      REAL D(26),E(4)
      OPEN (UNIT=4,STATUS ='SCRATCH')
      OPEN (UNIT=2,FILE=OUTPUT,STATUS='NEW',ACCESS ='DIRECT',
     * FORM='FORMATTED',RECL=132)
      LT4 = 1
      LT3 = 1
      DO 3500 I2 = 1, 21
      READ (4, 41,REC=LT3) TITLE
      WRITE (2,40,REC = LT4) '!', TITLE
40    FORMAT (1A1,1A130)
41    FORMAT (A130)
      LT3 = LT3 + 1
      LT4 = LT4 + 1
3500  CONTINUE
      DO 3600 I = 1, (LT2 - 1)
       DATA (D(Z),Z = 1,22) /22*Z00/
      READ (4,*,REC=LT3,ERR=3550) (D(Z), Z=1, 22)
      READ (4,75,REC=LT3,ERR=3575) D3,(E(Z), Z=1, 4)
75     FORMAT (A109,4F4.0)
3450  WRITE (2,80, REC = LT4) '!',(D(Z),Z = 1,22),(E(Z),Z=1,4)
80    FORMAT (A1,F7.2,2X,2(F4.0,1X),2(F3.0,1X),2(F4.0,1X),F6.0,1X,
     * 2(F4.2,1X),2(F4.0,1X),4(F3.0,1X),2(F3.0,1X),2(F5.0,1X),
     * 2(F3.0,1X),2(F4.0,1X),2(F3.0,1X))
      LT3 = LT3 + 1
      LT4 = LT4 + 1
      GO TO 3600
3550    READ (4,95,REC=LT3) D1,D2
        REM = '***'
        IF (D1 .EQ. REM) THEN
        WRITE (2,96,REC =LT4) '!',D1,D2
        LT4 = LT4 + 1
        LT3 = LT3 + 1
 95     FORMAT (1A3,A128)
 96     FORMAT (A1,A3,A128)
        GO TO 3600
        END IF
        LT3 = LT3 + 1
        GO TO 3600
3575  WRITE (2,85, REC = LT4) '!',(D(Z),Z = 1,22),'%'
       LT4 = LT4 + 1
85    FORMAT (A1,F7.2,2X,2(F4.0,1X),2(F3.0,1X),2(F4.0,1X),F6.0,1X,
     * 2(F4.2,1X),2(F4.0,1X),4(F3.0,1X),2(F3.0,1X),2(F5.0,1X),
     * 2(F3.0,1X),A1)
3600  CONTINUE
```

```
      CLOSE (UNIT=4, STATUS = 'DELETE')
      END
C *****************************************************************************
C
C     SUBROUTINE ICMSE FOR SINGLE ENGINE IECMS REPORTS
C
C ***************************************************************************

      SUBROUTINE ICMSE (INPUT,LIT1,LT2)
      INTEGER LIT,LIT1,LT2,I,K
      CHARACTER*9 A1,B1,A2*44,A3*34,A4*31,B2*44,B3*34,B4*31,C1*3,C2*129
      CHARACTER*131 TITLE,BLANK2*44, BLANK3*34,INPUT*20,NOTE*9
      OPEN (UNIT=1, FILE= INPUT,STATUS='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT =4,STATUS ='SCRATCH',ACCESS='DIRECT',
     * FORM='FORMATTED', RECL=132)

      LT2 = 1
      LT3 = 1
      DO 2500 I = 1, 20
      READ (1,'(1A130)',REC=LT3) TITLE
2001  WRITE(4,2005,REC=LT2)  TITLE
2005   FORMAT (A130)
      LT2 = LT2 + 1
2490  LT3 = LT3 + 1
2500  CONTINUE
      READ (1,2050,REC=LT3) A1,A2,A3,A4
2050  FORMAT (1A9,1A44,1A34,1A31)
        READ (1,2061,REC=LT2) C1,C2
2061    FORMAT (A3,A129)
        IF (C1 .EQ. '***') THEN
        WRITE (4,2061,REC=LT3) C1,C2
        LT3 = LT3 + 1
        LT2 = LT2 + 1
        GO TO 2700
        END IF
      LT3 = LT3 + 1
2700  DO 2600 I = 1, (LIT1 - 20)
      READ (1,2050,REC=LT3,ERR=2600) B1,B2,B3,B4
        READ (1,2060,REC=LT3) C1,C2
2060    FORMAT (A3,A129)
        IF (C1 .EQ. '***') THEN
        WRITE (4,2060,REC=LT2) C1,C2
        LT3 = LT3 + 1
        LT2 = LT2 + 1
        GO TO 2600
        END IF
      BLANK2 = '                                            '
      LT3 = LT3 + 1
      BLANK3='                                  '
      NOTE = '***      '
      IF (A1 .EQ. B1) GO TO 2130
       GO TO 2065
2130  IF (A2 .EQ. BLANK2 .AND. A3 .EQ. BLANK3) THEN
        B4 = A4
        GO TO 2065
        END IF
      IF (B2 .EQ. BLANK2 .AND. B3 .EQ. BLANK3) THEN
        B2 = A2
        B3 = A3
        GO TO 2065
        END IF
      IF (A2 .EQ.BLANK2) B3 = A3
      IF (A3 .EQ. BLANK3) B2 = A2
```

```
2065  A1 = B1
      A2 = B2
      A3 = B3
      A4 = B4
      IF (A1 .EQ. NOTE) GO TO 2070
      IF (A2 .EQ. BLANK2 .OR. A3 .EQ. BLANK3) GO TO 2600
2070  WRITE (4,35, REC = LT2) A1, A2, A3, A4,'A'
35    FORMAT (1A9, 1A44, 1A34, 1A31,A1)
      LT2 = LT2 + 1
2600  CONTINUE
      END


C
C*******************************************************************************
C SUBROUTINE FINAL1     FOR IECMS SINGLE ENGINE REPORT
C***************************************************************************
C
      SUBROUTINE FINAL1(OUTPUT,LT2)
      INTEGER LT3,LIT1,K,I,I2,Z,LT2,LT4
      CHARACTER*131 TITLE,REM*3,REM1*3,D1*3,D2*128,S1*1,D3*85
      CHARACTER*20 OUTPUT
      REAL D(26),E(18)
      OPEN (UNIT=4,STATUS ='SCRATCH')
      OPEN (UNIT=2,FILE=OUTPUT,STATUS='NEW',ACCESS ='DIRECT',
     * FORM='FORMATTED',RECL=132)
      LT4 = 1
      LT3 = 1
      DO 3500 I2 = 1, 21
      READ (4, 41,REC=LT3) TITLE
      WRITE (2,40,REC = LT4) '!', TITLE
40    FORMAT (1A1,1A130)
41    FORMAT (A130)
      LT3 = LT3 + 1
      LT4 = LT4 + 1
3500  CONTINUE
      DO 3600 I = 1, (LT2 - 1)
       DATA (E(Z),Z = 1,18) /18*9.9/
      READ (4,'(A3)',REC =LT3) D1
       IF (D1 .EQ. '***') GO TO 3550
      READ (4,*,REC=LT3,ERR=3550) (D(Z), Z=1, 13)
      READ (4,*,REC=LT3,ERR=3575) (E(Z), Z=1, 18)
75     FORMAT (A85,5F5.1)
3450  WRITE (2,80, REC = LT4) '!',(E(Z),Z = 1,18)
80    FORMAT (A1,F7.2,3X,2(F4.0,3X),F4.0,2X,F6.0,3X,2(F5.2,3X),
     * F4.0,2X,2(F4.0,2X),F5.0,2X,F5.0,3X,F4.0,5X,3(F3.1,2X),
     * F4.0,3X,F3.0)
      LT3 = LT3 + 1
      LT4 = LT4 + 1
      GO TO 3600
3550    READ (4,95,REC=LT3) D1,D2
        REM = '***'
        IF (D1 .EQ. REM) THEN
        WRITE (2,96,REC =LT4) '!',D1,D2
        LT4 = LT4 + 1
        LT3 = LT3 + 1
 95     FORMAT (1A3,A128)
 96     FORMAT (A1,A3,A128)
        GO TO 3600
        END IF
        LT3 = LT3 + 1
        GO TO 3600
3575  WRITE (2,85, REC = LT4) '!',(D(Z),Z = 1,13)
        LT4 = LT4 + 1
```

```
       LT3 = LT3 + 1
85     FORMAT (A1,F7.2,3X,2(F4.0,3X),F4.0,2X,F6.0,3X,2(F5.2,3X),
     * F4.0,2X,2(F4.0,2X),F5.0,2X,F5.0,3X,F4.0)
3600  CONTINUE
C     CLOSE (UNIT=4, STATUS = 'DELETE')
      END
C
C***********************************************************************
C
C  CODE 32 SUBROUTINE
C
C***********************************************************************
C
      SUBROUTINE CODE32 (INPUT,OUTPUT,LIT1)
      INTEGER LT1,I,J,LIT1,Z
      CHARACTER*131 TITLE
      CHARACTER*20 INPUT, OUTPUT
      REAL D(14),F(24)
      OPEN (UNIT=1,FILE=INPUT,STATUS='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT=2,FILE=OUTPUT,STATUS='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      LT1 = 1
      DO 5010 I =1,14
      READ (1,'(1A131)',REC=I) TITLE
      WRITE (2,5000,REC =I) '!',TITLE
5000  FORMAT (A1,A131)
5010  CONTINUE
      DO 5100 J=15,LIT1
      READ(1,*,REC=J,ERR=5075) (D(Z),Z=1,14)
      WRITE (2,5020, REC=J) '!',(D(Z),Z=1,14)
5020  FORMAT (A1,F5.0,1X,F7.2,2X,6(F3.1,2X),F7.2)
      GO TO 5100
5075   READ (1,'(A131)',REC=J) TITLE
       WRITE (2,5080,REC=J) '!',TITLE
5080   FORMAT (A1,A131)
5100  CONTINUE
      END
C***************************************************************************
C
C     CODE 31 REPORTS
C
C***************************************************************************
      SUBROUTINE CODE 31(INPUT, OUTPUT, LIT1)
      CHARACTER*25 A1,D1,A2*6,A3*101,B1*6
      CHARACTER*20 INPUT, OUTPUT,TITLE*131
      REAL C(14)
      INTEGER I,Z
      OPEN (UNIT=1,FILE=INPUT,STATUS='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT=2,FILE=OUTPUT,STATUS='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      DO 5010 I =1,6
      READ (1,'(1A131)',REC=I) TITLE
      WRITE (2,5000,REC =I) TITLE
5000  FORMAT (A131)
5010  CONTINUE
      DO 5050 I =7,12
      READ (1,5020,REC=I) A1,A2,A3
5020   FORMAT (A25,A6,A101)
      WRITE (2,5030,REC=I) A1,A3
5030   FORMAT (6X,A25,A101)
5050  CONTINUE
      DO 1000 I=13,LIT1
```

```
      READ (1,100,REC=I)A1,A2
100   FORMAT (A25,A6)
        IF (A2 .EQ. 'LEFT :') THEN
        READ (1,200,REC=I) B1,(C(Z),Z=1,9)
C200     FORMAT(A31,5F3.0,F8.1,F6.1,F4.1,F3.0)
200     FORMAT (A31,2F7.0,F8.0,F7.0,F8.0,F10.1,2F8.1,F4.0)
        WRITE (2,300,REC=I) A2,A1,(C(Z),Z=1,9)
300     FORMAT (A6,A25,1X,5(F4.0,3X),F8.1,2X,F6.1,
     *  3X,F3.1,3X,F4.0)
        GO TO 900
      END IF
        IF (A2 .EQ. 'RIGHT:') THEN
        READ (1,250,REC=I) B1,(C(Z),Z=1,10)
250     FORMAT (A31,2F7.0,F8.0,F7.0,F8.0,F10.1,2F8.1,2F5.0)
C250     FORMAT(A6,5F3.0,F8.1,F6.1,F4.1,2F3.0)
        WRITE (2,340,REC=I) A2,D1,(C(Z),Z=1,10)
340     FORMAT (A6,A25,1X,5(F4.0,3X),F8.1,2X,F6.1,
     *  3X,F3.1,3X,2(F4.0,1X))
        GO TO 900
      END IF
5100  READ (1,'(A131)',REC=I) TITLE
      WRITE (2,'(A131)',REC=I) TITLE
900   D1 = A1
1000  CONTINUE
      END

C
C***********************************************************************
C
C  CODE 36 SUBROUTINE
C
C***********************************************************************
C
      SUBROUTINE CODE36 (INPUT,OUTPUT,LIT1)
      INTEGER LT1,I,LIT1,LT6,Z
      CHARACTER*131 TITLE
      CHARACTER*20 INPUT, OUTPUT,B1*132
      REAL F(26)
      OPEN (UNIT=1,FILE=INPUT,STATUS='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT=2,FILE=OUTPUT,STATUS='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=140)
      LT1 = 1
      DO 5010 I =1,14
      READ (1,'(1A131)',REC=I) TITLE
      WRITE (2,5000,REC =I) '!',TITLE
5000  FORMAT (A1,A131)
5010  CONTINUE
      DO 6100 I=15,LIT1
       READ (1,*,REC=I,ERR=6050) (F(Z),Z=1,26)
       WRITE (2,6010,REC=I) '!',(F(Z),Z=1,26)
6010   FORMAT(A1,F6.0,1X,F7.2,1X,2(F4.0,1X),4(F3.0,1X),F5.0,1X,
     * F4.2,1X,F5.1,1X,F5.2,1X,2(F4.0,1X),6(F4.0,1X),2(F5.0,1X),
     * 4(F4.0,1X))
      GO TO 6100
6050  READ (1,'(A132)',REC=I) B1
      WRITE (2,6060,REC=I) '!',B1
6060  FORMAT (A1,A132)
6100  CONTINUE
      END

C
C***********************************************************************
```

```
C
C  CODE 34 SUBROUTINE
C
C***************************************************************************
C
      SUBROUTINE CODE34 (INPUT,OUTPUT,LIT1)
      INTEGER LT1,I,LIT1,LT6,Z
      CHARACTER*131 TITLE
      CHARACTER*20 INPUT, OUTPUT,B1*132
      REAL D(17)
      OPEN (UNIT=1,FILE=INPUT,STATUS='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      OPEN (UNIT=2,FILE=OUTPUT,STATUS='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECL=132)
      LT1 = 1
      DO 5010 I =1,13
      READ (1,'(1A131)',REC=I) TITLE
      WRITE (2,5000,REC =I) '!',TITLE
5000  FORMAT (A1,A131)
5010  CONTINUE
      DO 7200 I =14,LIT1
      READ (1,*, REC = I, ERR=7100) (D(Z),Z=1,17)
      WRITE (2,7075,REC=I) '!',(D(Z),Z=1,17)
7075   FORMAT (A1,F6.0,1X,F6.2,1X,6(F4.0,1X),2(F3.0,1X),
     * 2(F5.0,1X),4(F4.0,1X),F7.2)
      GO TO 7200
7100  READ (1,'(A131)',REC=I) TITLE
      WRITE (2,7150,REC=I) '!', TITLE
7150  FORMAT (A1,A131)
7200  CONTINUE
      END
```

C. DATACHAN.FORTRAN

DATACHAN.FORTRAN was used to normalize the IECMS Single Engine Report data and to reduce the eighteen components to eleven by removing PDTIME, ALTITUDE, MACH NUMBER, ANGLE OF ATTACK, NOZZLE POSITION, FUEL FLOW, AND PLA.

```
*****************************************************************************
*****************************************************************************

                                                DATACHAN.FORTRAN

*****************************************************************************
C  **********************************************************************
C THIS PROGRAM WILL NORMALIZE AND REDUCE THE AMOUNT OF DATA FOR
C AN F-18 IECMS SINGLE ENGINE REPORT.
C
C  **********************************************************************
C
      REAL A(18)
      INTEGER N,INPUT,C1,D
      CHARACTER*16 FILE1,FILE2,AO*1,ANS*1, B1*3, B2*8
      CHARACTER*132 TITLE,T1*10,T2*21,T6*18,T7*16
      CHARACTER*7 T3,T4,T5, T8*24
10    PRINT *,'WHAT IS YOUR INPUT FILE?'
      READ '(A)',FILE1
      PRINT *,'WHAT IS YOUR OUTPUT FILE?'
      READ '(A)',FILE2
      PRINT *,'HOW MANY RECORDS IN YOUR INPUT FILE?'
      READ *, INPUT
      OPEN (UNIT=1,FILE=FILE1,STATUS='OLD', ACCESS='DIRECT',
     & FORM='FORMATTED',RECL=132)
      OPEN (UNIT=2, FILE=FILE2, STATUS='NEW', ACCESS='DIRECT',
     & FORM='FORMATTED',RECL=132)
      DO 50 I=1,14
      READ(1,45,REC=I,ERR=50) TITLE
      WRITE(2,45,REC=I) TITLE
45    FORMAT(1A132)
50    CONTINUE
      DO 60 I = 15,19
      READ(1,62,REC=I,ERR=60)T1,T2,T3,T4,T5,T6,T7,T8
62    FORMAT(A10,A21,3A7,A18,A16,A24)
      WRITE(2,63,REC=I)'!',T2,T4,T6,T8
63    FORMAT(A1,4X,A21,A7,A18,A24)
      D = I
60    CONTINUE
      C1 = D
      DO 500 I = 20,INPUT
      READ (1,100,REC=I,ERR=500) AO, (A(N),N=1,18)
100   FORMAT(A1,F7.2,3F7.0,F8.0,2F8.2,F7.0,2F6.0,3F7.0,F8.1,2F5.1,2F6.0)
       IF (A(15).EQ.A(16) .AND. A(17).EQ.A(18)) GO TO 500

      B1 = '! I'
      C1 = C1 + 1
      WRITE (2,200,REC=C1) B1,A(2),A(3),A(4),A(6),A(8),A(9),A(10),
```

```
     & A(14),A(15),A(16),A(17)
200   FORMAT (A3,2X,3(F5.1,2X),F5.2,2X,3(F5.1,2X),3(F3.1,2X),F5.1)
      C1 = C1 + 1
      B2 = '! D  1.0'
      WRITE (2,'(A8)',REC=C1) B2
500   CONTINUE
      PRINT *, 'DO YOU WANT ANOTHER RUN (Y OR N)?'
      READ '(A)', ANS
      IF (ANS .EQ. 'N') GO TO 1000
      GO TO 10
1000  END
```

APPENDIX C. *NEURAL WARE SCREEN DUMPS*

A. Two Output Cumulative Back-Propagation (Reduced Data Set) Network

```
              Type: Hetero-Associative        Learn Data: Alpha (sd3)
      Display Mode: Network                  Recall Data: Alpha (ad31a)
     Display Style: default                     User I/O: userio
  Control Strategy: backprop                L/R Schedule: backprop
      20001 Learn            0 Recall                0 Layer
         10 Aux 1            0 Aux 2                 0 Aux 3
L/R Schedule: backprop
   Recall Step                 1          0          0          0          0
     Input Clamp          0.0000     0.0000     0.0000     0.0000     0.0000
     Firing Density     100.0000     0.0000     0.0000     0.0000     0.0000
     Temperature          0.0000     0.0000     0.0000     0.0000     0.0000
     Gain                 1.0000     0.0000     0.0000     0.0000     0.0000
     Modifier             1.0000     0.0000     0.0000     0.0000     0.0000
   Learn Step               5000          0          0          0          0
     Coefficient 1        0.9000     0.0000     0.0000     0.0000     0.0000
     Coefficient 2        0.6000     0.0000     0.0000     0.0000     0.0000
     Coefficient 3        0.0000     0.0000     0.0000     0.0000     0.0000
     Temperature          0.0000     0.0000     0.0000     0.0000     0.0000
Layer: 1
       PEs: 1                                          Sum: Sum
   Spacing: 5        F' minimum: 0.00             Transfer: Linear
     Shape: Square                                  Output: Direct
     Scale: 1.00      Low Limit: 0.00           Error Func: Standard
    Offset: 0.00     High Limit: 9999.00             Learn: --None--
  Init Low: -0.100    Init High: 0.100        L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None
  PE: Bias
      1.000 Error Factor
      0.000 Sum              1.000 Transfer           1.000 Output
          0 Weights        -45.610 Error              0.000 Cumulative Error
Layer: In
       PEs: 11                                         Sum: Sum
   Spacing: 5        F' minimum: 0.00             Transfer: Linear
     Shape: Square                                  Output: Direct
     Scale: 1.00      Low Limit: -9999.00       Error Func: Standard
    Offset: 0.00     High Limit: 9999.00             Learn: --None--
  Init Low: -0.100    Init High: 0.100        L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None
  PE: 2
      1.000 Error Factor
      0.893 Sum              0.893 Transfer           0.893 Output
          0 Weights          0.000 Error              0.000 Cumulative Error
  PE: 3
      1.000 Error Factor
      0.760 Sum              0.760 Transfer           0.760 Output
          0 Weights          0.000 Error              0.000 Cumulative Error
  PE: 4
      1.000 Error Factor
      0.540 Sum              0.540 Transfer           0.540 Output
          0 Weights          0.000 Error              0.000 Cumulative Error
  PE: 5
      1.000 Error Factor
      0.220 Sum              0.220 Transfer           0.220 Output
          0 Weights         -0.000 Error              0.000 Cumulative Error
```

```
PE: 6
    1.000 Error Factor
    0.820 Sum              0.820 Transfer          0.820 Output
        0 Weights          0.000 Error             0.000 Cumulative Error
PE: 7
    1.000 Error Factor
    0.980 Sum              0.980 Transfer          0.980 Output
        0 Weights          0.000 Error             0.000 Cumulative Error
PE: 8
    1.000 Error Factor
    0.930 Sum              0.930 Transfer          0.930 Output
        0 Weights          0.000 Error             0.000 Cumulative Error
PE: 9
    1.000 Error Factor
    0.250 Sum              0.250 Transfer          0.250 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 10
    1.000 Error Factor
    0.700 Sum              0.700 Transfer          0.700 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 11
    1.000 Error Factor
    0.400 Sum              0.400 Transfer          0.400 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 12
    1.000 Error Factor
    0.908 Sum              0.908 Transfer          0.908 Output
        0 Weights          0.000 Error             0.000 Cumulative Error


Layer: Hidden 1
       PEs: 9                                          Sum: Sum
   Spacing: 5         F' minimum: 0.00            Transfer: Sigmoid
     Shape: Square                                  Output: Direct
     Scale: 1.00       Low Limit: -9999.00      Error Func: Standard
    Offset: 0.00      High Limit: 9999.00            Learn: Cum-Delta-Rule
  Init Low: -0.100     Init High: 0.100       L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None


PE: 13
    1.000 Error Factor
   -4.439 Sum              0.012 Transfer          0.012 Output
       12 Weights         -0.000 Error            -0.000 Cumulative Error
          Bias   +1.0000   +0.8260 V-a   -0.0000
             2   +0.8935   -0.8917 V-a   -0.0000
             3   +0.7600   -0.2505 V-a   -0.0000
             4   +0.5400   -0.1310 V-a   -0.0000
             5   +0.2200   +0.9425 V-a   -0.0000
             6   +0.8200   -1.1527 V-a   -0.0000
             7   +0.9804   -2.2085 V-a   -0.0000
             8   +0.9300   -1.7532 V-a   -0.0000
             9   +0.2500   +0.1676 V-a   -0.0000
            10   +0.7000   +0.2131 V-a   -0.0000
            11   +0.4000   +1.0090 V-a   -0.0000
            12   +0.9077   -0.2954 V-a   -0.0000
```

```
PE: 14
    1.000 Error Factor
   -4.612 Sum              0.010 Transfer          0.010 Output
       12 Weights         -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   +0.7450 V-a   -0.0000
               2   +0.8935   -0.8507 V-a   -0.0000
               3   +0.7600   -0.1981 V-a   -0.0000
               4   +0.5400   -0.2389 V-a   -0.0000
               5   +0.2200   +0.7688 V-a   -0.0000
               6   +0.8200   -1.2008 V-a   -0.0000
               7   +0.9804   -2.0721 V-a   -0.0000
               8   +0.9300   -1.6411 V-a   -0.0000
               9   +0.2500   +0.1107 V-a   -0.0000
              10   +0.7000   +0.0446 V-a   -0.0000
              11   +0.4000   +0.7349 V-a   -0.0000
              12   +0.9077   -0.3271 V-a   -0.0000
PE: 15
    1.000 Error Factor
   -4.629 Sum              0.010 Transfer          0.010 Output
       12 Weights         -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   +0.8352 V-a   -0.0000
               2   +0.8935   -1.1182 V-a   -0.0000
               3   +0.7600   -0.3957 V-a   -0.0000
               4   +0.5400   -0.1585 V-a   -0.0000
               5   +0.2200   +1.2830 V-a   -0.0000
               6   +0.8200   -1.0958 V-a   -0.0000
               7   +0.9804   -2.3393 V-a   -0.0000
               8   +0.9300   -1.9003 V-a   -0.0000
               9   +0.2500   +0.4060 V-a   -0.0000
              10   +0.7000   +0.1401 V-a   -0.0000
              11   +0.4000   +1.5510 V-a   -0.0000
              12   +0.9077   -0.2447 V-a   -0.0000
PE: 16
    1.000 Error Factor
   -4.672 Sum              0.009 Transfer          0.009 Output
       12 Weights         -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   +1.0030 V-a   -0.0000
               2   +0.8935   -1.1480 V-a   -0.0000
               3   +0.7600   -0.3804 V-a   -0.0000
               4   +0.5400   -0.0775 V-a   -0.0000
               5   +0.2200   +1.3976 V-a   -0.0000
               6   +0.8200   -1.1824 V-a   -0.0000
               7   +0.9804   -2.5093 V-a   -0.0000
               8   +0.9300   -1.9806 V-a   -0.0000
               9   +0.2500   +0.3680 V-a   -0.0000
              10   +0.7000   +0.3194 V-a   -0.0000
              11   +0.4000   +1.5290 V-a   -0.0000
              12   +0.9077   -0.3094 V-a   -0.0000
PE: 17
    1.000 Error Factor
   -4.186 Sum              0.015 Transfer          0.015 Output
       12 Weights         -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   +0.4252 V-a   -0.0000
               2   +0.8935   -0.7195 V-a   -0.0000
               3   +0.7600   -0.3902 V-a   -0.0000
               4   +0.5400   -0.2379 V-a   -0.0000
               5   +0.2200   +0.6460 V-a   -0.0000
               6   +0.8200   -1.0022 V-a   -0.0000
               7   +0.9804   -1.6917 V-a   -0.0000
               8   +0.9300   -1.4600 V-a   -0.0000
               9   +0.2500   +0.1659 V-a   -0.0000
              10   +0.7000   +0.1640 V-a   -0.0000
              11   +0.4000   +0.9004 V-a   -0.0000
              12   +0.9077   -0.4009 V-a   -0.0000
```

```
PE: 18
    1.000 Error Factor
   -4.576 Sum              0.010 Transfer            0.010 Output
       12 Weights         -0.000 Error              -0.000 Cumulative Error
           Bias   +1.0000   +0.5544 V-a   -0.0000
              2   +0.8935   -0.8481 V-a   -0.0000
              3   +0.7600   -0.3006 V-a   -0.0000
              4   +0.5400   -0.2967 V-a   -0.0000
              5   +0.2200   +0.6426 V-a   -0.0000
              6   +0.8200   -1.0566 V-a   -0.0000
              7   +0.9804   -1.9010 V-a   -0.0000
              8   +0.9300   -1.4587 V-a   -0.0000
              9   +0.2500   +0.1273 V-a   -0.0000
             10   +0.7000   +0.0071 V-a   -0.0000
             11   +0.4000   +0.6762 V-a   -0.0000
             12   +0.9077   -0.3809 V-a   -0.0000
PE: 19
    1.000 Error Factor
   -4.272 Sum              0.014 Transfer            0.014 Output
       12 Weights         -0.000 Error              -0.000 Cumulative Error
           Bias   +1.0000   +0.6216 V-a   -0.0000
              2   +0.8935   -0.8473 V-a   -0.0000
              3   +0.7600   -0.3066 V-a   -0.0000
              4   +0.5400   -0.0837 V-a   -0.0000
              5   +0.2200   +0.9050 V-a   -0.0000
              6   +0.8200   -1.1071 V-a   -0.0000
              7   +0.9804   -1.9617 V-a   -0.0000
              8   +0.9300   -1.5613 V-a   -0.0000
              9   +0.2500   +0.3530 V-a   -0.0000
             10   +0.7000   +0.1068 V-a   -0.0000
             11   +0.4000   +1.1643 V-a   -0.0000
             12   +0.9077   -0.4439 V-a   -0.0000
PE: 20
    1.000 Error Factor
   -4.453 Sum              0.012 Transfer            0.012 Output
       12 Weights         -0.000 Error              -0.000 Cumulative Error
           Bias   +1.0000   +0.8519 V-a   -0.0000
              2   +0.8935   -0.8925 V-a   -0.0000
              3   +0.7600   -0.2941 V-a   -0.0000
              4   +0.5400   -0.2412 V-a   -0.0000
              5   +0.2200   +0.9807 V-a   -0.0000
              6   +0.8200   -1.1692 V-a   -0.0000
              7   +0.9804   -2.1854 V-a   -0.0000
              8   +0.9300   -1.7695 V-a   -0.0000
              9   +0.2500   +0.2558 V-a   -0.0000
             10   +0.7000   +0.1624 V-a   -0.0000
             11   +0.4000   +1.0540 V-a   -0.0000
             12   +0.9077   -0.2444 V-a   -0.0000
PE: 21
    1.000 Error Factor
   -4.256 Sum              0.014 Transfer            0.014 Output
       12 Weights         -0.000 Error              -0.000 Cumulative Error
           Bias   +1.0000   +0.5107 V-a   -0.0000
              2   +0.8935   -0.8490 V-a   -0.0000
              3   +0.7600   -0.2723 V-a   -0.0000
              4   +0.5400   -0.1829 V-a   -0.0000
              5   +0.2200   +0.8465 V-a   -0.0000
              6   +0.8200   -1.0835 V-a   -0.0000
              7   +0.9804   -1.7877 V-a   -0.0000
              8   +0.9300   -1.5373 V-a   -0.0000
              9   +0.2500   +0.2736 V-a   -0.0000
             10   +0.7000   +0.0974 V-a   -0.0000
             11   +0.4000   +0.9331 V-a   -0.0000
             12   +0.9077   -0.3614 V-a   -0.0000
```

```
Layer: Hidden 2
      PEs: 7                                          Sum: Sum
  Spacing: 5       F' minimum: 0.00              Transfer: Sigmoid
    Shape: Square                                  Output: Direct
    Scale: 1.00     Low Limit: -9999.00       Error Func: Standard
   Offset: 0.00    High Limit: 9999.00             Learn: Cum-Delta-Rule
 Init Low: -0.100   Init High: 0.100         L/R Schedule: (Network)
 Winner 1: None                                  Winner 2: None
 PE: 22
     1.000 Error Factor
     1.508 Sum              0.819 Transfer          0.819 Output
        10 Weights          0.000 Error             0.000 Cumulative Error
             Bias   +1.0000   +1.6174 V-a   +0.0000
               13   +0.0117   -1.0215 V-a   +0.0000
               14   +0.0098   -1.0884 V-a   +0.0000
               15   +0.0097   -1.2227 V-a   +0.0000
               16   +0.0093   -1.3663 V-a   +0.0000
               17   +0.0150   -0.9476 V-a   +0.0000
               18   +0.0102   -0.9131 V-a   +0.0000
               19   +0.0138   -0.9416 V-a   +0.0000
               20   +0.0115   -1.0802 V-a   +0.0000
               21   +0.0140   -1.0014 V-a   +0.0000
 PE: 23
     1.000 Error Factor
     1.690 Sum              0.844 Transfer          0.844 Output
        10 Weights          0.000 Error             0.000 Cumulative Error
             Bias   +1.0000   +1.8041 V-a   +0.0000
               13   +0.0117   -1.2269 V-a   +0.0000
               14   +0.0098   -1.1012 V-a   +0.0000
               15   +0.0097   -1.3728 V-a   +0.0000
               16   +0.0093   -1.4209 V-a   +0.0000
               17   +0.0150   -0.8634 V-a   +0.0000
               18   +0.0102   -0.9255 V-a   +0.0000
               19   +0.0138   -1.0224 V-a   +0.0000
               20   +0.0115   -1.1883 V-a   +0.0000
               21   +0.0140   -0.8917 V-a   +0.0000
 PE: 24
     1.000 Error Factor
     1.412 Sum              0.804 Transfer          0.804 Output
        10 Weights          0.000 Error             0.000 Cumulative Error
             Bias   +1.0000   +1.5195 V-a   +0.0000
               13   +0.0117   -1.1041 V-a   +0.0000
               14   +0.0098   -0.9726 V-a   +0.0000
               15   +0.0097   -1.2565 V-a   +0.0000
               16   +0.0093   -1.2762 V-a   +0.0000
               17   +0.0150   -0.8476 V-a   +0.0000
               18   +0.0102   -0.8646 V-a   +0.0000
               19   +0.0138   -1.0442 V-a   +0.0000
               20   +0.0115   -0.9915 V-a   +0.0000
               21   +0.0140   -0.9545 V-a   +0.0000
 PE: 25
     1.000 Error Factor
     1.633 Sum              0.837 Transfer          0.837 Output
        10 Weights          0.000 Error             0.000 Cumulative Error
             Bias   +1.0000   +1.7468 V-a   +0.0000
               13   +0.0117   -1.1058 V-a   +0.0000
               14   +0.0098   -1.1103 V-a   +0.0000
               15   +0.0097   -1.2304 V-a   +0.0000
               16   +0.0093   -1.4369 V-a   +0.0000
               17   +0.0150   -0.9129 V-a   +0.0000
               18   +0.0102   -0.9159 V-a   +0.0000
               19   +0.0138   -1.0142 V-a   +0.0000
               20   +0.0115   -1.2014 V-a   +0.0000
               21   +0.0140   -0.9657 V-a   +0.0000
```

```
PE: 26
    1.000 Error Factor
    1.630 Sum             0.836 Transfer         0.836 Output
       10 Weights         0.000 Error            0.000 Cumulative Error
          Bias   +1.0000   +1.7423 V-a   +0.0000
            13   +0.0117   -1.1955 V-a   +0.0000
            14   +0.0098   -1.0237 V-a   +0.0000
            15   +0.0097   -1.3574 V-a   +0.0000
            16   +0.0093   -1.3923 V-a   +0.0000
            17   +0.0150   -0.7853 V-a   +0.0000
            18   +0.0102   -0.9071 V-a   +0.0000
            19   +0.0138   -1.1179 V-a   +0.0000
            20   +0.0115   -1.0868 V-a   +0.0000
            21   +0.0140   -0.9825 V-a   +0.0000
PE: 27
    1.000 Error Factor
    1.227 Sum             0.773 Transfer         0.773 Output
       10 Weights         0.000 Error            0.000 Cumulative Error
          Bias   +1.0000   +1.3273 V-a   +0.0000
            13   +0.0117   -1.0947 V-a   +0.0000
            14   +0.0098   -0.9395 V-a   +0.0000
            15   +0.0097   -1.1437 V-a   +0.0000
            16   +0.0093   -1.2790 V-a   +0.0000
            17   +0.0150   -0.7232 V-a   +0.0000
            18   +0.0102   -0.8073 V-a   +0.0000
            19   +0.0138   -0.8835 V-a   +0.0000
            20   +0.0115   -1.1269 V-a   +0.0000
            21   +0.0140   -0.8060 V-a   +0.0000
PE: 28
    1.000 Error Factor
    1.315 Sum             0.788 Transfer         0.788 Output
       10 Weights         0.000 Error            0.000 Cumulative Error
          Bias   +1.0000   +1.4186 V-a   +0.0000
            13   +0.0117   -0.9820 V-a   +0.0000
            14   +0.0098   -0.9703 V-a   +0.0000
            15   +0.0097   -1.2304 V-a   +0.0000
            16   +0.0093   -1.2663 V-a   +0.0000
            17   +0.0150   -0.8252 V-a   +0.0000
            18   +0.0102   -0.9065 V-a   +0.0000
            19   +0.0138   -0.8723 V-a   +0.0000
            20   +0.0115   -1.1429 V-a   +0.0000
            21   +0.0140   -0.8601 V-a   +0.0000
Layer: Out
      PEs: 2                                         Sum: Sum
  Spacing: 5       F' minimum: 0.00             Transfer: Sigmoid
    Shape: Square                                 Output: Direct
    Scale: 1.00     Low Limit: -9999.00       Error Func: Standard
   Offset: 0.00    High Limit: 9999.00             Learn: Cum-Delta-Rule
 Init Low: -0.100   Init High: 0.100        L/R Schedule: (Network)
 Winner 1: None                                Winner 2: None
PE: 29
    1.000 Error Factor
   -8.991 Sum             0.000 Transfer         0.000 Output
        8 Weights        -0.000 Error           -0.000 Cumulative Error
          Bias   +1.0000   +5.1909 V-a   -0.0000
            22   +0.8187   -2.4754 V-a   -0.0000
            23   +0.8442   -2.6202 V-a   -0.0000
            24   +0.8041   -2.4155 V-a   -0.0000
            25   +0.8367   -2.5664 V-a   -0.0000
            26   +0.8361   -2.6781 V-a   -0.0000
            27   +0.7733   -2.2310 V-a   -0.0000
            28   +0.7884   -2.3960 V-a   -0.0000
```

```
PE: 30
    1.000 Error Factor
    8.994 Sum             1.000 Transfer          1.000 Output
        8 Weights         0.000 Error             0.000 Cumulative Error
          Bias   +1.0000   -5.1925 V-a   +0.0000
            22   +0.8187   +2.5096 V-a   +0.0000
            23   +0.8442   +2.6929 V-a   +0.0000
            24   +0.8041   +2.4101 V-a   +0.0000
            25   +0.8367   +2.6414 V-a   +0.0000
            26   +0.8361   +2.5211 V-a   +0.0000
            27   +0.7733   +2.3276 V-a   +0.0000
            28   +0.7884   +2.2859 V-a   +0.0000
```

B. Three Output Cumulative Back-Propagation (Reduced Data Set) Network

```
             Type: Hetero-Associative       Learn Data: Alpha (pat2)
     Display Mode: Network                 Recall Data: Alpha (pat2)
    Display Style: default                    User I/O: userio
 Control Strategy: backprop               L/R Schedule: backprop
    22001 Learn                 0 Recall                0 Layer
       10 Aux 1                 0 Aux 2                 0 Aux 3
L/R Schedule: backprop
   Recall Step                 1           0           0           0           0
     Input Clamp          0.0000      0.0000      0.0000      0.0000      0.0000
     Firing Density     100.0000      0.0000      0.0000      0.0000      0.0000
     Temperature          0.0000      0.0000      0.0000      0.0000      0.0000
     Gain                 1.0000      0.0000      0.0000      0.0000      0.0000
     Modifier             1.0000      0.0000      0.0000      0.0000      0.0000
   Learn Step               5000           0           0           0           0
     Coefficient 1        0.9000      0.0000      0.0000      0.0000      0.0000
     Coefficient 2        0.6000      0.0000      0.0000      0.0000      0.0000
     Coefficient 3        0.0000      0.0000      0.0000      0.0000      0.0000
     Temperature          0.0000      0.0000      0.0000      0.0000      0.0000
Layer: 1
        PEs: 1                                          Sum: Sum
    Spacing: 5        F' minimum: 0.00             Transfer: Linear
      Shape: Square                                  Output: Direct
      Scale: 1.00      Low Limit: 0.00           Error Func: Standard
     Offset: 0.00     High Limit: 9999.00             Learn: --None--
   Init Low: -0.100    Init High: 0.100        L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
   PE: Bias
       1.000 Error Factor
       0.000 Sum             1.000 Transfer          1.000 Output
           0 Weights      -227.940 Error             0.000 Cumulative Error
Layer: In
        PEs: 11                                         Sum: Sum
    Spacing: 5        F' minimum: 0.00             Transfer: Linear
      Shape: Square                                  Output: Direct
      Scale: 1.00      Low Limit: -9999.00       Error Func: Standard
     Offset: 0.00     High Limit: 9999.00             Learn: --None--
   Init Low: -0.100    Init High: 0.100        L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
   PE: 2
       1.000 Error Factor
       0.042 Sum             0.042 Transfer          0.042 Output
           0 Weights        -0.000 Error             0.000 Cumulative Error
   PE: 3
       1.000 Error Factor
```

```
      0.300 Sum            0.300 Transfer         0.300 Output
          0 Weights       -0.000 Error            0.000 Cumulative Error
  PE: 4
      1.000 Error Factor
     -0.040 Sum           -0.040 Transfer        -0.040 Output
          0 Weights        0.000 Error            0.000 Cumulative Error
  PE: 5
      1.000 Error Factor
      0.100 Sum            0.100 Transfer         0.100 Output
          0 Weights        0.000 Error            0.000 Cumulative Error
  PE: 6
      1.000 Error Factor
      0.026 Sum            0.026 Transfer         0.026 Output
          0 Weights       -0.000 Error            0.000 Cumulative Error
  PE: 7
      1.000 Error Factor
      0.000 Sum            0.000 Transfer         0.000 Output
          0 Weights       -0.000 Error            0.000 Cumulative Error
  PE: 8
      1.000 Error Factor
      0.000 Sum            0.000 Transfer         0.000 Output
          0 Weights       -0.000 Error            0.000 Cumulative Error
  PE: 9
      1.000 Error Factor
      0.075 Sum            0.075 Transfer         0.075 Output
          0 Weights        0.000 Error            0.000 Cumulative Error
  PE: 10
      1.000 Error Factor
      0.000 Sum            0.000 Transfer         0.000 Output
          0 Weights        0.000 Error            0.000 Cumulative Error
  PE: 11
      1.000 Error Factor
      0.100 Sum            0.100 Transfer         0.100 Output
          0 Weights        0.000 Error            0.000 Cumulative Error
  PE: 12
      1.000 Error Factor
      0.492 Sum            0.492 Transfer         0.492 Output
          0 Weights        0.000 Error            0.000 Cumulative Error
Layer: Hidden 1
        PEs: 9                                       Sum: Sum
    Spacing: 5        F' minimum: 0.00          Transfer: Sigmoid
      Shape: Square                               Output: Direct
      Scale: 1.00      Low Limit: -9999.00    Error Func: Standard
     Offset: 0.00     High Limit: 9999.00          Learn: Cum-Delta-Rule
   Init Low: -0.100    Init High: 0.100      L/R Schedule: (Network)
   Winner 1: None                               Winner 2: None
  PE: 13
      1.000 Error Factor
     -3.765 Sum            0.023 Transfer         0.023 Output
         12 Weights       -0.000 Error           -0.000 Cumulative Error
              Bias   +1.0000   -1.1667 V-a   -0.0000
                 2   +0.0419   +3.0979 V-a   -0.0000
                 3   +0.3000   +1.0749 V-a   -0.0000
                 4   -0.0400   -3.5827 V-a   +0.0000
                 5   +0.1000   +0.0527 V-a   -0.0000
                 6   +0.0260   +2.4288 V-a   -0.0000
                 7   +0.0000   +5.9489 V-a   +0.0000
                 8   +0.0000   +4.2240 V-a   +0.0000
                 9   +0.0750   -0.0224 V-a   -0.0000
                10   +0.0000   -1.8836 V-a   +0.0000
                11   +0.1000   -2.2255 V-a   -0.0000
                12   +0.4923   -6.1705 V-a   -0.0000
```

```
PE: 14
    1.000 Error Factor
   -3.206 Sum             0.039 Transfer          0.039 Output
       12 Weights        -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   -0.5442 V-a   -0.0000
               2   +0.0419   +0.9826 V-a   -0.0000
               3   +0.3000   +0.0893 V-a   -0.0000
               4   -0.0400   -1.4654 V-a   +0.0000
               5   +0.1000   -0.7151 V-a   -0.0000
               6   +0.0260   +1.6197 V-a   -0.0000
               7   +0.0000   +2.9350 V-a   +0.0000
               8   +0.0000   +2.7426 V-a   +0.0000
               9   +0.0750   -0.2452 V-a   -0.0000
              10   +0.0000   -1.8498 V-a   +0.0000
              11   +0.1000   -1.5375 V-a   -0.0000
              12   +0.4923   -5.2541 V-a   -0.0000


PE: 15
    1.000 Error Factor
   -3.239 Sum             0.038 Transfer          0.038 Output
       12 Weights        -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   -0.0963 V-a   -0.0000
               2   +0.0419   +0.4315 V-a   -0.0000
               3   +0.3000   +0.0107 V-a   -0.0000
               4   -0.0400   -1.0180 V-a   +0.0000
               5   +0.1000   -1.1122 V-a   -0.0000
               6   +0.0260   +1.5638 V-a   -0.0000
               7   +0.0000   +2.4999 V-a   +0.0000
               8   +0.0000   +2.8205 V-a   +0.0000
               9   +0.0750   -0.0173 V-a   -0.0000
              10   +0.0000   -1.8438 V-a   +0.0000
              11   +0.1000   -1.5610 V-a   -0.0000
              12   +0.4923   -6.0456 V-a   -0.0000


PE: 16
    1.000 Error Factor
   -3.338 Sum             0.034 Transfer          0.034 Output
       12 Weights        -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   -0.0676 V-a   -0.0000
               2   +0.0419   +0.4315 V-a   -0.0000
               3   +0.3000   -0.0299 V-a   -0.0000
               4   -0.0400   -0.9878 V-a   +0.0000
               5   +0.1000   -1.1805 V-a   -0.0000
               6   +0.0260   +1.7439 V-a   -0.0000
               7   +0.0000   +2.5658 V-a   +0.0000
               8   +0.0000   +3.0129 V-a   +0.0000
               9   +0.0750   -0.0720 V-a   -0.0000
              10   +0.0000   -2.0360 V-a   +0.0000
              11   +0.1000   -1.6744 V-a   -0.0000
              12   +0.4923   -6.2433 V-a   -0.0000
```

```
PE: 17
    1.000 Error Factor
   -3.282 Sum            0.036 Transfer          0.036 Output
       12 Weights       -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   +0.0725 V-a   -0.0000
               2   +0.0419   +0.2264 V-a   -0.0000
               3   +0.3000   -0.0180 V-a   -0.0000
               4   -0.0400   -0.6424 V-a   +0.0000
               5   +0.1000   -1.1790 V-a   -0.0000
               6   +0.0260   +1.4252 V-a   -0.0000
               7   +0.0000   +2.1158 V-a   +0.0000
               8   +0.0000   +2.5148 V-a   +0.0000
               9   +0.0750   +0.2518 V-a   -0.0000
              10   +0.0000   -1.6668 V-a   +0.0000
              11   +0.1000   -1.2612 V-a   -0.0000
              12   +0.4923   -6.4919 V-a   -0.0000
PE: 18
    1.000 Error Factor
   -3.257 Sum            0.037 Transfer          0.037 Output
       12 Weights       -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   -0.2328 V-a   -0.0000
               2   +0.0419   +0.5996 V-a   -0.0000
               3   +0.3000   -0.0699 V-a   -0.0000
               4   -0.0400   -1.2012 V-a   +0.0000
               5   +0.1000   -0.9365 V-a   -0.0000
               6   +0.0260   +1.6041 V-a   -0.0000
               7   +0.0000   +2.8292 V-a   +0.0000
               8   +0.0000   +2.8967 V-a   +0.0000
               9   +0.0750   -0.1300 V-a   -0.0000
              10   +0.0000   -1.9817 V-a   +0.0000
              11   +0.1000   -1.6641 V-a   -0.0000
              12   +0.4923   -5.7860 V-a   -0.0000
PE: 19
    1.000 Error Factor
   -3.919 Sum            0.019 Transfer          0.019 Output
       12 Weights       -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   -1.1374 V-a   -0.0000
               2   +0.0419   +3.2130 V-a   -0.0000
               3   +0.3000   +1.1641 V-a   -0.0000
               4   -0.0400   -3.7349 V-a   +0.0000
               5   +0.1000   +0.2077 V-a   -0.0000
               6   +0.0260   +2.6935 V-a   -0.0000
               7   +0.0000   +6.4006 V-a   +0.0000
               8   +0.0000   +4.4188 V-a   +0.0000
               9   +0.0750   -0.1465 V-a   -0.0000
              10   +0.0000   -2.0230 V-a   +0.0000
              11   +0.1000   -2.3400 V-a   -0.0000
              12   +0.4923   -6.6239 V-a   -0.0000
PE: 20
    1.000 Error Factor
   -3.809 Sum            0.022 Transfer          0.022 Output
       12 Weights       -0.000 Error            -0.000 Cumulative Error
            Bias   +1.0000   -1.1782 V-a   -0.0000
               2   +0.0419   +2.9028 V-a   -0.0000
               3   +0.3000   +0.9186 V-a   -0.0000
               4   -0.0400   -3.4656 V-a   +0.0000
               5   +0.1000   +0.1573 V-a   -0.0000
               6   +0.0260   +2.4758 V-a   -0.0000
               7   +0.0000   +5.8662 V-a   +0.0000
               8   +0.0000   +4.1394 V-a   +0.0000
               9   +0.0750   -0.0291 V-a   -0.0000
              10   +0.0000   -1.8791 V-a   +0.0000
              11   +0.1000   -2.0153 V-a   -0.0000
              12   +0.4923   -6.1808 V-a   -0.0000
```

```
PE: 21
    1.000 Error Factor
   -3.192 Sum            0.039 Transfer          0.039 Output
       12 Weights       -0.000 Error            -0.000 Cumulative Error
          Bias   +1.0000   -0.2407 V-a   -0.0000
             2   +0.0419   +0.4395 V-a   -0.0000
             3   +0.3000   -0.0363 V-a   -0.0000
             4   -0.0400   -0.6505 V-a   +0.0000
             5   +0.1000   -1.0331 V-a   -0.0000
             6   +0.0260   +1.3209 V-a   -0.0000
             7   +0.0000   +1.9190 V-a   +0.0000
             8   +0.0000   +2.1434 V-a   +0.0000
             9   +0.0750   +0.2799 V-a   -0.0000
            10   +0.0000   -1.4055 V-a   +0.0000
            11   +0.1000   -0.8836 V-a   -0.0000
            12   +0.4923   -5.7854 V-a   -0.0000


Layer: Hidden 2
       PEs: 7                                          Sum: Sum
   Spacing: 5         F' minimum: 0.00            Transfer: Sigmoid
     Shape: Square                                  Output: Direct
     Scale: 1.00       Low Limit: -9999.00      Error Func: Standard
    Offset: 0.00      High Limit: 9999.00            Learn: Cum-Delta-Rule
  Init Low: -0.100     Init High: 0.100        L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None


PE: 22
    1.000 Error Factor
    1.354 Sum            0.795 Transfer          0.795 Output
       10 Weights        0.000 Error             0.000 Cumulative Error
          Bias   +1.0000   +1.8662 V-a   +0.0000
            13   +0.0227   -1.7850 V-a   +0.0000
            14   +0.0389   -1.7097 V-a   +0.0000
            15   +0.0377   -1.7775 V-a   +0.0000
            16   +0.0343   -1.9143 V-a   +0.0000
            17   +0.0362   -1.7624 V-a   +0.0000
            18   +0.0371   -1.7104 V-a   +0.0000
            19   +0.0195   -2.0018 V-a   +0.0000
            20   +0.0217   -1.9146 V-a   +0.0000
            21   +0.0395   -1.6398 V-a   +0.0000


PE: 23
    1.000 Error Factor
    1.598 Sum            0.832 Transfer          0.832 Output
       10 Weights        0.000 Error             0.000 Cumulative Error
          Bias   +1.0000   +2.1583 V-a   +0.0000
            13   +0.0227   -1.9406 V-a   +0.0000
            14   +0.0389   -1.9279 V-a   +0.0000
            15   +0.0377   -1.9889 V-a   +0.0000
            16   +0.0343   -2.0419 V-a   +0.0000
            17   +0.0362   -1.9159 V-a   +0.0000
            18   +0.0371   -1.9766 V-a   +0.0000
            19   +0.0195   -2.1314 V-a   +0.0000
            20   +0.0217   -1.9994 V-a   +0.0000
            21   +0.0395   -1.7457 V-a   +0.0000
```

```
PE: 24
    1.000 Error Factor
    5.871 Sum              0.997 Transfer          0.997 Output
       10 Weights         -0.000 Error            -0.000 Cumulative Error
           Bias   +1.0000   +6.3932 V-a   -0.0000
             13   +0.0227   +1.6762 V-a   -0.0000
             14   +0.0389   -1.6490 V-a   -0.0000
             15   +0.0377   -2.8410 V-a   -0.0000
             16   +0.0343   -2.8422 V-a   -0.0000
             17   +0.0362   -3.7084 V-a   -0.0000
             18   +0.0371   -2.3341 V-a   -0.0000
             19   +0.0195   +1.5449 V-a   -0.0000
             20   +0.0217   +1.2102 V-a   -0.0000
             21   +0.0395   -3.2193 V-a   -0.0000


PE: 25
    1.000 Error Factor
    1.680 Sum              0.843 Transfer          0.843 Output
       10 Weights          0.000 Error             0.000 Cumulative Error
           Bias   +1.0000   +2.2507 V-a   +0.0000
             13   +0.0227   -2.0950 V-a   +0.0000
             14   +0.0389   -1.8361 V-a   +0.0000
             15   +0.0377   -1.9647 V-a   +0.0000
             16   +0.0343   -2.1731 V-a   +0.0000
             17   +0.0362   -2.1251 V-a   +0.0000
             18   +0.0371   -1.9283 V-a   +0.0000
             19   +0.0195   -2.2529 V-a   +0.0000
             20   +0.0217   -2.0621 V-a   +0.0000
             21   +0.0395   -1.6675 V-a   +0.0000


PE: 26
    1.000 Error Factor
    1.318 Sum              0.789 Transfer          0.789 Output
       10 Weights          0.000 Error             0.000 Cumulative Error
           Bias   +1.0000   +1.8217 V-a   +0.0000
             13   +0.0227   -1.8537 V-a   +0.0000
             14   +0.0389   -1.5746 V-a   +0.0000
             15   +0.0377   -1.8367 V-a   +0.0000
             16   +0.0343   -1.7711 V-a   +0.0000
             17   +0.0362   -1.8046 V-a   +0.0000
             18   +0.0371   -1.8002 V-a   +0.0000
             19   +0.0195   -1.9576 V-a   +0.0000
             20   +0.0217   -1.8915 V-a   +0.0000
             21   +0.0395   -1.4855 V-a   +0.0000


PE: 27
    1.000 Error Factor
    1.244 Sum              0.776 Transfer          0.776 Output
       10 Weights          0.000 Error             0.000 Cumulative Error
           Bias   +1.0000   +1.7396 V-a   +0.0000
             13   +0.0227   -1.8111 V-a   +0.0000
             14   +0.0389   -1.5554 V-a   +0.0000
             15   +0.0377   -1.7400 V-a   +0.0000
             16   +0.0343   -1.9030 V-a   +0.0000
             17   +0.0362   -1.7190 V-a   +0.0000
             18   +0.0371   -1.8241 V-a   +0.0000
             19   +0.0195   -1.8231 V-a   +0.0000
             20   +0.0217   -1.7039 V-a   +0.0000
             21   +0.0395   -1.5447 V-a   +0.0000
```

```
PE: 28
    1.000 Error Factor
    1.631 Sum            0.836 Transfer         0.836 Output
       10 Weights        0.000 Error            0.000 Cumulative Error
           Bias   +1.0000   +2.1969 V-a   +0.0000
             13   +0.0227   -2.0304 V-a   +0.0000
             14   +0.0389   -1.8135 V-a   +0.0000
             15   +0.0377   -2.0708 V-a   +0.0000
             16   +0.0343   -2.0821 V-a   +0.0000
             17   +0.0362   -1.9657 V-a   +0.0000
             18   +0.0371   -2.0131 V-a   +0.0000
             19   +0.0195   -2.2131 V-a   +0.0000
             20   +0.0217   -1.9824 V-a   +0.0000
             21   +0.0395   -1.7200 V-a   +0.0000


Layer: output
       PEs: 3                                          Sum: Sum
   Spacing: 20      F' minimum: 0.00              Transfer: Sigmoid
     Shape: Square                                  Output: Direct
     Scale: 1.00     Low Limit: -9999.00        Error Func: Standard
    Offset: 0.00    High Limit: 9999.00              Learn: Cum-Delta-Rule
  Init Low: -0.100   Init High: 0.100         L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None


PE: flameout
    1.000 Error Factor
    8.406 Sum            1.000 Transfer         1.000 Output
        8 Weights        0.000 Error            0.000 Cumulative Error
           Bias   +1.0000   -6.1786 V-a   +0.0000
             22   +0.7948   +2.7730 V-a   +0.0000
             23   +0.8317   +2.9731 V-a   +0.0000
             24   +0.9972   +0.6372 V-a   +0.0000
             25   +0.8429   +2.9021 V-a   +0.0000
             26   +0.7889   +2.8269 V-a   +0.0000
             27   +0.7762   +2.7735 V-a   +0.0000
             28   +0.8363   +2.9213 V-a   +0.0000

PE: normal
    1.000 Error Factor
   -7.602 Sum            0.000 Transfer         0.000 Output
        8 Weights       -0.000 Error           -0.000 Cumulative Error
           Bias   +1.0000   -3.5108 V-a   -0.0000
             22   +0.7948   -2.3678 V-a   -0.0000
             23   +0.8317   -2.6618 V-a   -0.0000
             24   +0.9972   +8.3585 V-a   -0.0000
             25   +0.8429   -2.9574 V-a   -0.0000
             26   +0.7889   -2.2651 V-a   -0.0000
             27   +0.7762   -2.1215 V-a   -0.0000
             28   +0.8363   -2.8750 V-a   -0.0000

PE: oil pres
    1.000 Error Factor
  -13.937 Sum            0.000 Transfer         0.000 Output
        8 Weights        0.000 Error            0.000 Cumulative Error
           Bias   +1.0000   +3.4938 V-a   +0.0000
             22   +0.7948   -2.0171 V-a   +0.0000
             23   +0.8317   -2.0869 V-a   +0.0000
             24   +0.9972   -7.8695 V-a   +0.0000
             25   +0.8429   -1.9392 V-a   +0.0000
             26   +0.7889   -1.9229 V-a   +0.0000
             27   +0.7762   -2.0347 V-a   +0.0000
             28   +0.8363   -1.8099 V-a   +0.0000
```

C. Two Output Back-Propagation/Kohenan Network

```
              Type: Hetero-Associative        Learn Data: Alpha (alldata3)
      Display Mode: Network                  Recall Data: Alpha (ad31a)
     Display Style: default                     User I/O: userio
  Control Strategy: backprop                L/R Schedule: backprop
       6001 Learn                0 Recall                  0 Layer
         10 Aux 1                0 Aux 2                   0 Aux 3
L/R Schedule: backprop
   Recall Step                1          0          0          0          0
     Input Clamp         0.0000     0.0000     0.0000     0.0000     0.0000
     Firing Density    100.0000     0.0000     0.0000     0.0000     0.0000
     Temperature         0.0000     0.0000     0.0000     0.0000     0.0000
     Gain                1.0000     0.0000     0.0000     0.0000     0.0000
     Modifier            1.0000     0.0000     0.0000     0.0000     0.0000
   Learn Step              5000          0          0          0          0
     Coefficient 1       0.9000     0.0000     0.0000     0.0000     0.0000
     Coefficient 2       0.6000     0.0000     0.0000     0.0000     0.0000
     Coefficient 3       0.0000     0.0000     0.0000     0.0000     0.0000
     Temperature         0.0000     0.0000     0.0000     0.0000     0.0000
Layer: 1
       PEs: 1                                          Sum: Sum
   Spacing: 5       F' minimum: 0.00              Transfer: Linear
     Shape: Square                                  Output: Direct
     Scale: 1.00     Low Limit: 0.00            Error Func: Standard
    Offset: 0.00    High Limit: 9999.00              Learn: --None--
  Init Low: -0.100   Init High: 0.100         L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None
  PE: Bias
      1.000 Error Factor
      0.000 Sum            1.000 Transfer          1.000 Output
          0 Weights        3.508 Error             0.000 Cumulative Error


Layer: In
       PEs: 11                                         Sum: Sum
   Spacing: 5       F' minimum: 0.00              Transfer: Linear
     Shape: Square                                  Output: Direct
     Scale: 1.00     Low Limit: -9999.00        Error Func: Standard
    Offset: 0.00    High Limit: 9999.00              Learn: --None--
  Init Low: -0.100   Init High: 0.100         L/R Schedule: (Network)
  Winner 1: None                                  Winner 2: None

  PE: 2
      1.000 Error Factor
      0.652 Sum            0.652 Transfer          0.652 Output
          0 Weights        0.001 Error             0.000 Cumulative Error
  PE: 3
      1.000 Error Factor
      0.620 Sum            0.620 Transfer          0.620 Output
          0 Weights        0.000 Error             0.000 Cumulative Error
  PE: 4
      1.000 Error Factor
      0.340 Sum            0.340 Transfer          0.340 Output
          0 Weights       -0.000 Error             0.000 Cumulative Error
  PE: 5
      1.000 Error Factor
      0.650 Sum            0.650 Transfer          0.650 Output
          0 Weights       -0.000 Error             0.000 Cumulative Error
  PE: 6
      1.000 Error Factor
      0.815 Sum            0.815 Transfer          0.815 Output
          0 Weights        0.001 Error             0.000 Cumulative Error
```

```
PE: 7
    1.000 Error Factor
    0.990 Sum            0.990 Transfer        0.990 Output
        0 Weights        0.002 Error           0.000 Cumulative Error
PE: 8
    1.000 Error Factor
    0.960 Sum            0.960 Transfer        0.960 Output
        0 Weights        0.001 Error           0.000 Cumulative Error
PE: 9
    1.000 Error Factor
    0.325 Sum            0.325 Transfer        0.325 Output
        0 Weights        0.000 Error           0.000 Cumulative Error
PE: 10
    1.000 Error Factor
    0.400 Sum            0.400 Transfer        0.400 Output
        0 Weights        0.000 Error           0.000 Cumulative Error
PE: 11
    1.000 Error Factor
    1.000 Sum            1.000 Transfer        1.000 Output
        0 Weights       -0.001 Error           0.000 Cumulative Error
PE: 12
    1.000 Error Factor
    0.977 Sum            0.977 Transfer        0.977 Output
        0 Weights       -0.000 Error           0.000 Cumulative Error


Layer: Hidden 1
       PEs: 9                                        Sum: Sum
   Spacing: 5        F' minimum: 0.00           Transfer: Sigmoid
     Shape: Square                                Output: Direct
     Scale: 1.00      Low Limit: -9999.00     Error Func: Standard
    Offset: 0.00     High Limit: 9999.00           Learn: Cum-Delta-Rule
  Init Low: -0.100    Init High: 0.100      L/R Schedule: (Network)
  Winner 1: None                                Winner 2: None


PE: 13
    1.000 Error Factor
    4.821 Sum            0.992 Transfer        0.992 Output
       12 Weights        0.000 Error           0.006 Cumulative Error
          Bias   +1.0000   -3.7153 V-a   +0.0000
             2   +0.6516   +2.8311 V-a   +0.0000
             3   +0.6200   +1.1326 V-a   +0.0000
             4   +0.3400   -0.5909 V-a   +0.0000
             5   +0.6500   -0.5363 V-a   +0.0000
             6   +0.8150   +2.4178 V-a   +0.0000
             7   +0.9902   +4.8215 V-a   +0.0000
             8   +0.9600   +2.5019 V-a   +0.0000
             9   +0.3250   +0.6940 V-a   +0.0000
            10   +0.4000   +0.7441 V-a   +0.0000
            11   +1.0000   -2.7802 V-a   +0.0000
            12   +0.9769   -0.3586 V-a   +0.0000
```

```
PE: 14
    1.000 Error Factor
  -14.482 Sum             0.000 Transfer          0.000 Output
       12 Weights         0.000 Error             0.005 Cumulative Error
             Bias  +1.0000  -1.6181 V-a  +0.0000
                2  +0.6516  -1.0787 V-a  +0.0000
                3  +0.6200  -0.9516 V-a  +0.0000
                4  +0.3400  -1.7368 V-a  +0.0000
                5  +0.6500  -0.3107 V-a  +0.0000
                6  +0.8150  -2.1106 V-a  +0.0000
                7  +0.9902  -2.5915 V-a  +0.0000
                8  +0.9600  -2.4448 V-a  +0.0000
                9  +0.3250  -0.9064 V-a  +0.0000
               10  +0.4000  +0.1262 V-a  +0.0000
               11  +1.0000  -2.2796 V-a  +0.0000
               12  +0.9769  -1.6602 V-a  +0.0000
PE: 15
    1.000 Error Factor
  -14.953 Sum             0.000 Transfer          0.000 Output
       12 Weights         0.000 Error             0.000 Cumulative Error
             Bias  +1.0000  -2.9920 V-a  +0.0000
                2  +0.6516  +0.2531 V-a  +0.0000
                3  +0.6200  -0.4984 V-a  +0.0000
                4  +0.3400  -0.5595 V-a  +0.0000
                5  +0.6500  -1.5117 V-a  +0.0000
                6  +0.8150  -0.7467 V-a  +0.0000
                7  +0.9902  +0.2389 V-a  +0.0000
                8  +0.9600  -0.5643 V-a  +0.0000
                9  +0.3250  -1.9461 V-a  +0.0000
               10  +0.4000  -1.0173 V-a  +0.0000
               11  +1.0000  -7.0754 V-a  +0.0000
               12  +0.9769  -1.6537 V-a  +0.0000
PE: 16
    1.000 Error Factor
   -4.546 Sum             0.010 Transfer          0.010 Output
       12 Weights        -0.000 Error            -0.009 Cumulative Error
             Bias  +1.0000  +1.4712 V-a  -0.0001
                2  +0.6516  -1.2398 V-a  -0.0001
                3  +0.6200  -0.1954 V-a  -0.0001
                4  +0.3400  -0.9578 V-a  -0.0000
                5  +0.6500  -0.0819 V-a  -0.0001
                6  +0.8150  -1.3101 V-a  -0.0001
                7  +0.9902  -2.3165 V-a  -0.0001
                8  +0.9600  -1.9458 V-a  -0.0001
                9  +0.3250  +0.1459 V-a  -0.0000
               10  +0.4000  +1.9958 V-a  -0.0000
               11  +1.0000  -0.2847 V-a  -0.0001
               12  +0.9769  -0.0418 V-a  -0.0001
PE: 17
    1.000 Error Factor
   -7.886 Sum             0.000 Transfer          0.000 Output
       12 Weights         0.000 Error             0.000 Cumulative Error
             Bias  +1.0000  -1.8952 V-a  +0.0000
                2  +0.6516  +0.0841 V-a  +0.0000
                3  +0.6200  -0.4588 V-a  +0.0000
                4  +0.3400  -0.6421 V-a  +0.0000
                5  +0.6500  -0.7454 V-a  +0.0000
                6  +0.8150  -0.5615 V-a  +0.0000
                7  +0.9902  -0.0367 V-a  +0.0000
                8  +0.9600  -0.4350 V-a  +0.0000
                9  +0.3250  -0.6421 V-a  +0.0000
               10  +0.4000  -0.5083 V-a  +0.0000
               11  +1.0000  -2.7580 V-a  +0.0000
               12  +0.9769  -1.0001 V-a  +0.0000
```

```
PE: 18
    1.000 Error Factor
    4.133 Sum              0.984 Transfer          0.984 Output
       12 Weights          0.000 Error             0.006 Cumulative Error
            Bias  +1.0000   -2.7879 V-a   +0.0001
               2  +0.6516   +2.4179 V-a   +0.0001
               3  +0.6200   +0.8553 V-a   +0.0001
               4  +0.3400   -0.4420 V-a   +0.0000
               5  +0.6500   -0.9712 V-a   +0.0001
               6  +0.8150   +2.0743 V-a   +0.0001
               7  +0.9902   +4.1809 V-a   +0.0001
               8  +0.9600   +2.2203 V-a   +0.0001
               9  +0.3250   +0.3761 V-a   +0.0000
              10  +0.4000   +0.7431 V-a   +0.0000
              11  +1.0000   -2.6989 V-a   +0.0001
              12  +0.9769   -0.0885 V-a   +0.0001
PE: 19
    1.000 Error Factor
    2.690 Sum              0.936 Transfer          0.936 Output
       12 Weights          0.000 Error             0.005 Cumulative Error
            Bias  +1.0000   -2.8328 V-a   +0.0003
               2  +0.6516   +1.9129 V-a   +0.0002
               3  +0.6200   +0.6852 V-a   +0.0002
               4  +0.3400   -0.6248 V-a   +0.0001
               5  +0.6500   -0.6164 V-a   +0.0002
               6  +0.8150   +1.5022 V-a   +0.0002
               7  +0.9902   +3.0884 V-a   +0.0003
               8  +0.9600   +1.6192 V-a   +0.0002
               9  +0.3250   +0.3598 V-a   +0.0001
              10  +0.4000   +0.7135 V-a   +0.0001
              11  +1.0000   -1.6878 V-a   +0.0003
              12  +0.9769   -0.0894 V-a   +0.0003
PE: 20
    1.000 Error Factor
   -5.012 Sum              0.007 Transfer          0.007 Output
       12 Weights          0.000 Error             0.000 Cumulative Error
            Bias  +1.0000   -3.1682 V-a   +0.0000
               2  +0.6516   +0.2556 V-a   +0.0000
               3  +0.6200   -0.6709 V-a   +0.0000
               4  +0.3400   -0.0395 V-a   +0.0000
               5  +0.6500   -0.5780 V-a   +0.0000
               6  +0.8150   +0.2479 V-a   +0.0000
               7  +0.9902   +0.8515 V-a   +0.0000
               8  +0.9600   +0.6264 V-a   +0.0000
               9  +0.3250   -0.0673 V-a   +0.0000
              10  +0.4000   +0.2284 V-a   +0.0000
              11  +1.0000   -1.5616 V-a   +0.0000
              12  +0.9769   -1.3924 V-a   +0.0000
PE: 21
    1.000 Error Factor
   -7.644 Sum              0.000 Transfer          0.000 Output
       12 Weights          0.000 Error             0.000 Cumulative Error
            Bias  +1.0000   -1.9728 V-a   +0.0000
               2  +0.6516   -0.0424 V-a   +0.0000
               3  +0.6200   -0.4315 V-a   +0.0000
               4  +0.3400   -0.4988 V-a   +0.0000
               5  +0.6500   -0.9111 V-a   +0.0000
               6  +0.8150   -0.4817 V-a   +0.0000
               7  +0.9902   +0.0096 V-a   +0.0000
               8  +0.9600   -0.3208 V-a   +0.0000
               9  +0.3250   -0.6288 V-a   +0.0000
              10  +0.4000   -0.4480 V-a   +0.0000
              11  +1.0000   -2.4845 V-a   +0.0000
              12  +0.9769   -1.0801 V-a   +0.0000
```

```
Layer: kohenan
      PEs: 14                                          Sum: Sum
  Spacing: 5        F' minimum: 0.00              Transfer: Linear
    Shape: Square                                   Output: One-Highest
    Scale: 1.00      Low Limit: -9999.00        Error Func: Standard
   Offset: 0.00     High Limit: 9999.00              Learn: KohonenN
 Init Low: -0.100    Init High: 0.100          L/R Schedule: (Network)
 Winner 1: None                                   Winner 2: None
 PE: 22
     1.000 Error Factor
     5.047 Sum               5.047 Transfer           1.000 Output
         9 Weights           0.003 Error              0.003 Cumulative Error
               13    +0.9920    +1.7692 V-a    -0.6998
               14    +0.0000    +0.0000 V-a    -0.0000
               15    +0.0000    +0.0000 V-a    -0.0000
               16    +0.0105    +0.0188 V-a    -0.0080
               17    +0.0004    +0.0007 V-a    -0.0003
               18    +0.9842    +1.7553 V-a    -0.6943
               19    +0.9364    +1.6698 V-a    -0.6594
               20    +0.0066    +0.0118 V-a    -0.0048
               21    +0.0005    +0.0009 V-a    -0.0004
 PE: 23
     1.000 Error Factor
    -1.009 Sum              -1.009 Transfer           0.000 Output
         9 Weights           0.000 Error              0.000 Cumulative Error
               13    +0.9920    -0.8758 V-a    +0.0000
               14    +0.0000    -1.5152 V-a    +0.0000
               15    +0.0000    -0.2872 V-a    +0.0000
               16    +0.0105    -0.7391 V-a    +0.0000
               17    +0.0004    +0.1593 V-a    +0.0000
               18    +0.9842    +0.8257 V-a    +0.0000
               19    +0.9364    -1.0048 V-a    +0.0000
               20    +0.0066    -0.7268 V-a    +0.0000
               21    +0.0005    +1.7503 V-a    +0.0000
 PE: 24
     1.000 Error Factor
     0.990 Sum               0.990 Transfer           0.000 Output
         9 Weights           0.002 Error              0.002 Cumulative Error
               13    +0.9920    +0.3955 V-a    -0.3648
               14    +0.0000    +2.8267 V-a    -2.0669
               15    +0.0000    +0.0581 V-a    -0.0688
               16    +0.0105    +0.5701 V-a    -0.4048
               17    +0.0004    +0.3509 V-a    -0.3086
               18    +0.9842    +0.5371 V-a    -0.4938
               19    +0.9364    +0.0664 V-a    -0.0583
               20    +0.0066    +0.0893 V-a    -0.0799
               21    +0.0005    +0.3182 V-a    -0.2795

 PE: 25
     1.000 Error Factor
     0.000 Sum               0.000 Transfer           0.000 Output
         9 Weights          -0.000 Error             -0.000 Cumulative Error
               13    +0.9920    +0.0000 V-a    +0.4997
               14    +0.0000    +0.0000 V-a    +1.2859
               15    +0.0000    +0.0000 V-a    -1.4169
               16    +0.0105    +0.0000 V-a    -0.7473
               17    +0.0004    +0.0000 V-a    +1.3455
               18    +0.9842    +0.0000 V-a    -0.3430
               19    +0.9364    +0.0000 V-a    -0.5564
               20    +0.0066    +0.0000 V-a    +1.4883
               21    +0.0005    +0.0000 V-a    -0.2794
```

```
PE: 26
    1.000 Error Factor
   -1.416 Sum            -1.416 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.9920   -1.0157 V-a   +0.0000
              14   +0.0000   +0.5788 V-a   +0.0000
              15   +0.0000   -1.1238 V-a   +0.0000
              16   +0.0105   -1.0125 V-a   +0.0000
              17   +0.0004   +1.4842 V-a   +0.0000
              18   +0.9842   -0.8497 V-a   +0.0000
              19   +0.9364   +0.4744 V-a   +0.0000
              20   +0.0066   -1.0164 V-a   +0.0000
              21   +0.0005   +1.0781 V-a   +0.0000


PE: 27
    1.000 Error Factor
   -2.251 Sum            -2.251 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13   +0.9920   -0.5411 V-a   +0.0000
              14   +0.0000   -0.2682 V-a   +0.0000
              15   +0.0000   -1.5872 V-a   +0.0000
              16   +0.0105   -0.5884 V-a   +0.0000
              17   +0.0004   -0.2185 V-a   +0.0000
              18   +0.9842   -1.6531 V-a   +0.0000
              19   +0.9364   -0.0977 V-a   +0.0000
              20   +0.0066   +1.4503 V-a   +0.0000
              21   +0.0005   +0.9362 V-a   +0.0000


PE: 28
    1.000 Error Factor
    0.000 Sum             0.000 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.9920   +0.0000 V-a   +1.4567
              14   +0.0000   +0.0000 V-a   -0.0326
              15   +0.0000   +0.0000 V-a   +1.2921
              16   +0.0105   +0.0000 V-a   -0.9111
              17   +0.0004   +0.0000 V-a   -1.4701
              18   +0.9842   +0.0000 V-a   +0.9688
              19   +0.9364   +0.0000 V-a   -0.7732
              20   +0.0066   +0.0000 V-a   -0.3833
              21   +0.0005   +0.0000 V-a   +0.7300


PE: 31
    1.000 Error Factor
    0.000 Sum             0.000 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.9920   +0.0000 V-a   +0.6458
              14   +0.0000   +0.0000 V-a   +0.7095
              15   +0.0000   +0.0000 V-a   +0.5052
              16   +0.0105   +0.0003 V-a   -1.2052
              17   +0.0004   +0.0000 V-a   +0.0432
              18   +0.9842   +0.0000 V-a   +1.5573
              19   +0.9364   +0.0001 V-a   +1.3496
              20   +0.0066   +0.0000 V-a   -0.6258
              21   +0.0005   +0.0000 V-a   -1.3157
```

```
PE: 32
    1.000 Error Factor
   -1.153 Sum            -1.153 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13    +0.9920    -0.5489 V-a    +0.0000
              14    +0.0000    -0.5302 V-a    +0.0000
              15    +0.0000    -1.1705 V-a    +0.0000
              16    +0.0105    -1.1742 V-a    +0.0000
              17    +0.0004    +0.6341 V-a    +0.0000
              18    +0.9842    +0.2127 V-a    +0.0000
              19    +0.9364    -0.8491 V-a    +0.0000
              20    +0.0066    -1.4365 V-a    +0.0000
              21    +0.0005    -1.5611 V-a    +0.0000


PE: 33
    1.000 Error Factor
   -2.112 Sum            -2.112 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13    +0.9920    -0.7185 V-a    +0.0000
              14    +0.0000    +0.1040 V-a    +0.0000
              15    +0.0000    +1.4955 V-a    +0.0000
              16    +0.0105    -1.7741 V-a    +0.0000
              17    +0.0004    +0.7434 V-a    +0.0000
              18    +0.9842    -0.4654 V-a    +0.0000
              19    +0.9364    -0.9821 V-a    +0.0000
              20    +0.0066    -0.4024 V-a    +0.0000
              21    +0.0005    -1.0924 V-a    +0.0000


PE: 34
    1.000 Error Factor
    0.000 Sum             0.000 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13    +0.9920    +0.0000 V-a    -0.0958
              14    +0.0000    +0.0000 V-a    +1.4605
              15    +0.0000    +0.0000 V-a    -1.0927
              16    +0.0105    +0.0001 V-a    -1.2403
              17    +0.0004    +0.0000 V-a    +0.4426
              18    +0.9842    +0.0000 V-a    +1.4298
              19    +0.9364    +0.0001 V-a    +1.0554
              20    +0.0066    +0.0000 V-a    +0.8395
              21    +0.0005    +0.0000 V-a    -0.2570


PE: 35
    1.000 Error Factor
   -1.753 Sum            -1.753 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13    +0.9920    -1.2402 V-a    +0.0000
              14    +0.0000    -0.7124 V-a    +0.0000
              15    +0.0000    -0.9259 V-a    +0.0000
              16    +0.0105    -1.5648 V-a    +0.0000
              17    +0.0004    +0.6340 V-a    +0.0000
              18    +0.9842    +0.4445 V-a    +0.0000
              19    +0.9364    -1.0159 V-a    +0.0000
              20    +0.0066    +1.1782 V-a    +0.0000
              21    +0.0005    -0.7928 V-a    +0.0000
```

```
PE: 36
    1.000 Error Factor
    0.546 Sum            0.546 Transfer        0.000 Output
        9 Weights       -0.003 Error          -0.003 Cumulative Error
              13  +0.9920  +0.0924 V-a  -0.0595
              14  +0.0000  +0.1553 V-a  -0.1012
              15  +0.0000  +0.0220 V-a  -0.0143
              16  +0.0105  +2.9686 V-a  -1.9280
              17  +0.0004  +0.1731 V-a  -0.1123
              18  +0.9842  +0.2189 V-a  -0.1412
              19  +0.9364  +0.2212 V-a  -0.1428
              20  +0.0066  +0.0497 V-a  -0.0322
              21  +0.0005  +0.1571 V-a  -0.1020


PE: 37
    1.000 Error Factor
   -3.422 Sum           -3.422 Transfer        0.000 Output
        9 Weights        0.000 Error           0.000 Cumulative Error
              13  +0.9920  -1.1674 V-a  +0.0000
              14  +0.0000  +0.4230 V-a  +0.0000
              15  +0.0000  +1.3325 V-a  +0.0000
              16  +0.0105  -0.5264 V-a  +0.0000
              17  +0.0004  -0.9192 V-a  +0.0000
              18  +0.9842  -1.2841 V-a  +0.0000
              19  +0.9364  -1.0523 V-a  +0.0000
              20  +0.0066  -1.3241 V-a  +0.0000
              21  +0.0005  -0.2260 V-a  +0.0000


Layer: Out
       PEs: 2                                     Sum: Sum
   Spacing: 5       F' minimum: 0.00         Transfer: Sigmoid
     Shape: Square                             Output: Direct
     Scale: 1.00     Low Limit: -9999.00   Error Func: Standard
    Offset: 0.00    High Limit: 9999.00         Learn: Cum-Delta-Rule
  Init Low: -0.100   Init High: 0.100    L/R Schedule: (Network)
  Winner 1: None                             Winner 2: None

PE: 29
    1.000 Error Factor
   -3.846 Sum            0.021 Transfer        0.021 Output
       14 Weights       -0.000 Error          -0.021 Cumulative Error
              22  +1.0000  -3.8463 V-a  -0.0004
              23  +0.0000  -0.0541 V-a  +0.0000
              24  +0.0000  -2.2814 V-a  +0.0000
              25  +0.0000  +0.1674 V-a  +0.0000
              26  +0.0000  -0.0145 V-a  +0.0000
              27  +0.0000  -0.0991 V-a  +0.0000
              28  +0.0000  +0.0303 V-a  +0.0000
              31  +0.0000  +0.1212 V-a  +0.0000
              32  +0.0000  +0.0319 V-a  +0.0000
              33  +0.0000  +0.0348 V-a  +0.0000
              34  +0.0000  +0.1687 V-a  +0.0000
              35  +0.0000  -0.0107 V-a  +0.0000
              36  +0.0000  +3.8955 V-a  +0.0000
              37  +0.0000  +0.0234 V-a  +0.0000
```

```
PE: 30
    1.000 Error Factor
    3.846 Sum            0.979 Transfer         0.979 Output
       14 Weights        0.000 Error            0.021 Cumulative Error
             22   +1.0000   +3.8463 V-a   +0.0004
             23   +0.0000   -0.0324 V-a   +0.0000
             24   +0.0000   +2.2820 V-a   +0.0000
             25   +0.0000   -0.0540 V-a   +0.0000
             26   +0.0000   -0.0557 V-a   +0.0000
             27   +0.0000   -0.0693 V-a   +0.0000
             28   +0.0000   -0.1681 V-a   +0.0000
             31   +0.0000   -0.0574 V-a   +0.0000
             32   +0.0000   -0.0515 V-a   +0.0000
             33   +0.0000   +0.0707 V-a   +0.0000
             34   +0.0000   -0.0632 V-a   +0.0000
             35   +0.0000   +0.0114 V-a   +0.0000
             36   +0.0000   -3.8955 V-a   +0.0000
             37   +0.0000   +0.0617 V-a   +0.0000
```

D. Three Output Back-Propagation/Kohenan Network (16 Element)

```
           Type: Hetero-Associative       Learn Data: Alpha (pat2)
   Display Mode: Network                 Recall Data: Alpha (ad31a)
  Display Style: default                    User I/O: userio
Control Strategy: backprop               L/R Schedule: backprop
    15001 Learn              0 Recall              0 Layer
       10 Aux 1              0 Aux 2               0 Aux 3
L/R Schedule: backprop
   Recall Step              1          0          0          0          0
     Input Clamp       0.0000     0.0000     0.0000     0.0000     0.0000
     Firing Density  100.0000     0.0000     0.0000     0.0000     0.0000
     Temperature       0.0000     0.0000     0.0000     0.0000     0.0000
     Gain              1.0000     0.0000     0.0000     0.0000     0.0000
     Modifier          1.0000     0.0000     0.0000     0.0000     0.0000
   Learn Step            5000          0          0          0          0
     Coefficient 1     0.9000     0.0000     0.0000     0.0000     0.0000
     Coefficient 2     0.6000     0.0000     0.0000     0.0000     0.0000
     Coefficient 3     0.0000     0.0000     0.0000     0.0000     0.0000
     Temperature       0.0000     0.0000     0.0000     0.0000     0.0000
```

```
Layer: 1
       PEs: 1                                       Sum: Sum
   Spacing: 5        F' minimum: 0.00          Transfer: Linear
     Shape: Square                               Output: Direct
     Scale: 1.00      Low Limit: 0.00        Error Func: Standard
    Offset: 0.00     High Limit: 9999.00          Learn: --None--
  Init Low: -0.100    Init High: 0.100     L/R Schedule: (Network)
  Winner 1: None                               Winner 2: None
  PE: Bias
      1.000 Error Factor
      0.000 Sum            1.000 Transfer         1.000 Output
          0 Weights       30.918 Error            0.000 Cumulative Error
Layer: In
       PEs: 11                                      Sum: Sum
   Spacing: 5        F' minimum: 0.00          Transfer: Linear
     Shape: Square                               Output: Direct
```

```
   Scale: 1.00     Low Limit: -9999.00      Error Func: Standard
  Offset: 0.00    High Limit: 9999.00            Learn: --None--
Init Low: -0.100   Init High: 0.100       L/R Schedule: (Network)
Winner 1: None                                Winner 2: None
PE: 2
    1.000 Error Factor
    0.358 Sum              0.358 Transfer          0.358 Output
        0 Weights          0.002 Error             0.000 Cumulative Error
PE: 3
    1.000 Error Factor
    0.440 Sum              0.440 Transfer          0.440 Output
        0 Weights          0.000 Error             0.000 Cumulative Error
PE: 4
    1.000 Error Factor
    0.420 Sum              0.420 Transfer          0.420 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 5
    1.000 Error Factor
    0.100 Sum              0.100 Transfer          0.100 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 6
    1.000 Error Factor
    0.553 Sum              0.553 Transfer          0.553 Output
        0 Weights          0.002 Error             0.000 Cumulative Error
PE: 7
    1.000 Error Factor
    0.677 Sum              0.677 Transfer          0.677 Output
        0 Weights          0.003 Error             0.000 Cumulative Error
PE: 8
    1.000 Error Factor
    0.810 Sum              0.810 Transfer          0.810 Output
        0 Weights          0.002 Error             0.000 Cumulative Error
PE: 9
    1.000 Error Factor
    0.100 Sum              0.100 Transfer          0.100 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 10
    1.000 Error Factor
    0.300 Sum              0.300 Transfer          0.300 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
PE: 11
    1.000 Error Factor
    0.000 Sum              0.000 Transfer          0.000 Output
        0 Weights         -0.001 Error             0.000 Cumulative Error
PE: 12
    1.000 Error Factor
    0.785 Sum              0.785 Transfer          0.785 Output
        0 Weights         -0.000 Error             0.000 Cumulative Error
Layer: Hidden 1
     PEs: 9                                           Sum: Sum
 Spacing: 5       F' minimum: 0.00               Transfer: Sigmoid
   Shape: Square                                   Output: Direct
   Scale: 1.00     Low Limit: -9999.00      Error Func: Standard
  Offset: 0.00    High Limit: 9999.00            Learn: Cum-Delta-Rule
Init Low: -0.100   Init High: 0.100       L/R Schedule: (Network)
Winner 1: None                                Winner 2: None


PE: 13
    1.000 Error Factor
    1.860 Sum              0.865 Transfer          0.865 Output
       12 Weights          0.000 Error             0.003 Cumulative Error
             Bias    +1.0000    +0.2086 V-a    +0.0004
```

```
                     2    +0.3581    -0.4467 V-a    +0.0001
                     3    +0.4400    -0.2045 V-a    +0.0002
                     4    +0.4200    -1.2094 V-a    +0.0002
                     5    +0.1000    +1.5251 V-a    +0.0000
                     6    +0.5530    -1.6666 V-a    +0.0002
                     7    +0.6765    -2.0220 V-a    +0.0002
                     8    +0.8100    -2.9549 V-a    +0.0003
                     9    +0.1000    -0.7454 V-a    +0.0000
                    10    +0.3000    +0.7198 V-a    +0.0001
                    11    +0.0000    +0.6797 V-a    +0.0000
                    12    +0.7846    +8.6649 V-a    +0.0003


PE: 14
    1.000 Error Factor
   -2.991 Sum              0.048 Transfer           0.048 Output
       12 Weights         -0.000 Error             -0.004 Cumulative Error
                  Bias    +1.0000    +2.3341 V-a    -0.0002
                     2    +0.3581    -2.0322 V-a    -0.0001
                     3    +0.4400    -0.4144 V-a    -0.0001
                     4    +0.4200    -0.6264 V-a    -0.0001
                     5    +0.1000    +1.3807 V-a    -0.0000
                     6    +0.5530    -2.7680 V-a    -0.0001
                     7    +0.6765    -4.7083 V-a    -0.0001
                     8    +0.8100    -4.1400 V-a    -0.0001
                     9    +0.1000    -0.1293 V-a    -0.0000
                    10    +0.3000    +0.9921 V-a    -0.0001
                    11    +0.0000    +1.3412 V-a    +0.0000
                    12    +0.7846    +4.4537 V-a    -0.0001


PE: 15
    1.000 Error Factor
   -3.755 Sum              0.023 Transfer           0.023 Output
       12 Weights          0.000 Error              0.000 Cumulative Error
                  Bias    +1.0000    -1.9552 V-a    +0.0000
                     2    +0.3581    -0.2326 V-a    +0.0000
                     3    +0.4400    -0.5193 V-a    +0.0000
                     4    +0.4200    -0.4185 V-a    +0.0000
                     5    +0.1000    -0.5388 V-a    +0.0000
                     6    +0.5530    -0.4867 V-a    +0.0000
                     7    +0.6765    -0.3392 V-a    +0.0000
                     8    +0.8100    -0.7469 V-a    +0.0000
                     9    +0.1000    -0.4996 V-a    +0.0000
                    10    +0.3000    -0.4626 V-a    +0.0000
                    11    +0.0000    -0.9305 V-a    +0.0000
                    12    +0.7846    +0.0438 V-a    +0.0000
PE: 16
    1.000 Error Factor
   -2.619 Sum              0.068 Transfer           0.068 Output
       12 Weights         -0.000 Error             -0.004 Cumulative Error
                  Bias    +1.0000    +2.3369 V-a    -0.0002
                     2    +0.3581    -1.7767 V-a    -0.0001
                     3    +0.4400    -0.4033 V-a    -0.0001
                     4    +0.4200    -0.8353 V-a    -0.0001
                     5    +0.1000    +1.3807 V-a    -0.0000
                     6    +0.5530    -2.7040 V-a    -0.0001
                     7    +0.6765    -4.1721 V-a    -0.0002
                     8    +0.8100    -4.1011 V-a    -0.0002
                     9    +0.1000    -0.1119 V-a    -0.0000
                    10    +0.3000    +0.9027 V-a    -0.0001
                    11    +0.0000    +0.7529 V-a    +0.0000
                    12    +0.7846    +4.3979 V-a    -0.0002
```

```
PE: 17
    1.000 Error Factor
    6.635 Sum             0.999 Transfer            0.999 Output
       12 Weights         0.000 Error               0.010 Cumulative Error
            Bias  +1.0000   -7.6161 V-a  +0.0000
               2  +0.3581   +0.1051 V-a  +0.0000
               3  +0.4400   -1.8522 V-a  +0.0000
               4  +0.4200   +2.4510 V-a  +0.0000
               5  +0.1000   -2.2465 V-a  +0.0000
               6  +0.5530   +2.6115 V-a  +0.0000
               7  +0.6765   +3.1116 V-a  +0.0000
               8  +0.8100   +3.7030 V-a  +0.0000
               9  +0.1000   -2.2198 V-a  +0.0000
              10  +0.3000   -1.7389 V-a  +0.0000
              11  +0.0000   -3.1979 V-a  +0.0000
              12  +0.7846  +10.7300 V-a  +0.0000
PE: 18
    1.000 Error Factor
   10.336 Sum             1.000 Transfer            1.000 Output
       12 Weights         0.000 Error               0.005 Cumulative Error
            Bias  +1.0000   +4.2156 V-a  +0.0000
               2  +0.3581   +0.4815 V-a  +0.0000
               3  +0.4400   +1.2563 V-a  +0.0000
               4  +0.4200   +0.0417 V-a  +0.0000
               5  +0.1000   +1.3521 V-a  +0.0000
               6  +0.5530   +0.1168 V-a  +0.0000
               7  +0.6765   -0.0324 V-a  +0.0000
               8  +0.8100   +0.1592 V-a  +0.0000
               9  +0.1000   -0.9494 V-a  +0.0000
              10  +0.3000   +0.1218 V-a  +0.0000
              11  +0.0000   -1.3935 V-a  +0.0000
              12  +0.7846   +6.5370 V-a  +0.0000
PE: 19
    1.000 Error Factor
   -3.073 Sum             0.044 Transfer            0.044 Output
       12 Weights        -0.000 Error              -0.002 Cumulative Error
            Bias  +1.0000   +0.4448 V-a  -0.0001
               2  +0.3581   -0.5504 V-a  -0.0000
               3  +0.4400   -0.0381 V-a  -0.0000
               4  +0.4200   -1.0242 V-a  -0.0000
               5  +0.1000   +0.0547 V-a  -0.0000
               6  +0.5530   -1.1231 V-a  -0.0000
               7  +0.6765   -1.4063 V-a  -0.0000
               8  +0.8100   -1.8646 V-a  -0.0000
               9  +0.1000   -0.3213 V-a  -0.0000
              10  +0.3000   -0.2804 V-a  -0.0000
              11  +0.0000   -0.3918 V-a  +0.0000
              12  +0.7846   +0.4074 V-a  -0.0000
PE: 20
    1.000 Error Factor
   -3.148 Sum             0.041 Transfer            0.041 Output
       12 Weights        -0.000 Error              -0.004 Cumulative Error
            Bias  +1.0000   +1.0572 V-a  -0.0002
               2  +0.3581   -2.9008 V-a  -0.0001
               3  +0.4400   -1.3198 V-a  -0.0001
               4  +0.4200   -0.1079 V-a  -0.0001
               5  +0.1000   +0.8598 V-a  -0.0000
               6  +0.5530   -3.0826 V-a  -0.0001
               7  +0.6765   -5.3008 V-a  -0.0001
               8  +0.8100   -4.6422 V-a  -0.0001
               9  +0.1000   -1.0306 V-a  -0.0000
              10  +0.3000   +0.9116 V-a  -0.0000
              11  +0.0000   +1.9041 V-a  +0.0000
              12  +0.7846   +7.9710 V-a  -0.0001
```

```
PE: 21
   1.000 Error Factor
  -3.446 Sum              0.031 Transfer          0.031 Output
      12 Weights         -0.000 Error            -0.004 Cumulative Error
          Bias   +1.0000   +2.2887 V-a   -0.0001
             2   +0.3581   -2.7172 V-a   -0.0000
             3   +0.4400   -0.8278 V-a   -0.0001
             4   +0.4200   -0.2328 V-a   -0.0001
             5   +0.1000   +1.1465 V-a   -0.0000
             6   +0.5530   -3.1762 V-a   -0.0001
             7   +0.6765   -5.2604 V-a   -0.0001
             8   +0.8100   -4.4198 V-a   -0.0001
             9   +0.1000   -0.2299 V-a   -0.0000
            10   +0.3000   +1.1461 V-a   -0.0000
            11   +0.0000   +2.0407 V-a   +0.0000
            12   +0.7846   +5.3025 V-a   -0.0001
```

```
Layer: kohonen
        PEs: 16                                      Sum: Sum
    Spacing: 5         F' minimum: 0.00         Transfer: Linear
      Shape: Square                               Output: One-Highest
      Scale: 1.00       Low Limit: -9999.00   Error Func: Standard
     Offset: 0.00      High Limit: 9999.00         Learn: KohonenN
   Init Low: -0.100     Init High: 0.100    L/R Schedule: (Network)
   Winner 1: None                               Winner 2: None
```

```
PE: 22
   1.000 Error Factor
   0.003 Sum              0.003 Transfer          0.000 Output
       9 Weights          0.000 Error             0.000 Cumulative Error
            13   +0.8653   -1.4480 V-a   +0.0000
            14   +0.0478   -0.2471 V-a   +0.0000
            15   +0.0229   -0.8777 V-a   +0.0000
            16   +0.0679   -0.8396 V-a   +0.0000
            17   +0.9987   +0.5546 V-a   +0.0000
            18   +1.0000   +0.9058 V-a   +0.0000
            19   +0.0442   -0.2257 V-a   +0.0000
            20   +0.0412   -1.5387 V-a   +0.0000
            21   +0.0309   -1.3492 V-a   +0.0000
```

```
PE: 23
    1.000 Error Factor
    2.300 Sum              2.300 Transfer          0.000 Output
        9 Weights         -0.000 Error            -0.000 Cumulative Error
              13    +0.8653    +0.2117 V-a    +0.0000
              14    +0.0478    +0.7361 V-a    +0.0000
              15    +0.0229    +0.8045 V-a    +0.0000
              16    +0.0679    +1.3774 V-a    +0.0000
              17    +0.9987    -0.2470 V-a    +0.0000
              18    +1.0000    +2.2215 V-a    +0.0000
              19    +0.0442    +0.5401 V-a    +0.0000
              20    +0.0412    -0.1472 V-a    +0.0000
              21    +0.0309    -0.7481 V-a    +0.0000


PE: 24
    1.000 Error Factor
   -0.186 Sum             -0.186 Transfer          0.000 Output
        9 Weights         -0.000 Error            -0.000 Cumulative Error
              13    +0.8653    -0.1853 V-a    +0.0000
              14    +0.0478    +1.0876 V-a    +0.0000
              15    +0.0229    -0.9795 V-a    +0.0000
              16    +0.0679    -1.2193 V-a    +0.0000
              17    +0.9987    -1.0382 V-a    +0.0000
              18    +1.0000    +1.0253 V-a    +0.0000
              19    +0.0442    -0.9061 V-a    +0.0000
              20    +0.0412    +1.2438 V-a    +0.0000
              21    +0.0309    +0.9161 V-a    +0.0000


PE: 25
    1.000 Error Factor
   -1.924 Sum             -1.924 Transfer          0.000 Output
        9 Weights         -0.000 Error            -0.000 Cumulative Error
              13    +0.8653    +0.1721 V-a    +0.0000
              14    +0.0478    -1.4172 V-a    +0.0000
              15    +0.0229    +0.9305 V-a    +0.0000
              16    +0.0679    +0.5629 V-a    +0.0000
              17    +0.9987    -1.3149 V-a    +0.0000
              18    +1.0000    -0.8175 V-a    +0.0000
              19    +0.0442    +1.2188 V-a    +0.0000
              20    +0.0412    -0.6220 V-a    +0.0000
              21    +0.0309    +1.2288 V-a    +0.0000


PE: 26
    1.000 Error Factor
    0.033 Sum              0.033 Transfer          0.000 Output
        9 Weights          0.000 Error             0.000 Cumulative Error
              13    +0.8653    +0.6518 V-a    +0.0000
              14    +0.0478    +0.7366 V-a    +0.0000
              15    +0.0229    +1.3734 V-a    +0.0000
              16    +0.0679    +0.8708 V-a    +0.0000
              17    +0.9987    -0.7768 V-a    +0.0000
              18    +1.0000    +0.2380 V-a    +0.0000
              19    +0.0442    -0.2152 V-a    +0.0000
              20    +0.0412    -1.4497 V-a    +0.0000
              21    +0.0309    -1.6062 V-a    +0.0000
```

```
PE: 27
    1.000 Error Factor
   -2.450 Sum            -2.450 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.8653   -0.3367 V-a   +0.0000
              14   +0.0478   +0.7300 V-a   +0.0000
              15   +0.0229   -0.0560 V-a   +0.0000
              16   +0.0679   +1.0209 V-a   +0.0000
              17   +0.9987   -1.4896 V-a   +0.0000
              18   +1.0000   -0.8221 V-a   +0.0000
              19   +0.0442   +1.9103 V-a   +0.0000
              20   +0.0412   -0.8741 V-a   +0.0000
              21   +0.0309   +0.0002 V-a   +0.0000


PE: 28
    1.000 Error Factor
   -1.456 Sum            -1.456 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.8653   +1.2931 V-a   +0.0000
              14   +0.0478   +0.1194 V-a   +0.0000
              15   +0.0229   -0.7081 V-a   +0.0000
              16   +0.0679   +0.1338 V-a   +0.0000
              17   +0.9987   -2.0246 V-a   +0.0000
              18   +1.0000   -0.5625 V-a   +0.0000
              19   +0.0442   -0.7931 V-a   +0.0000
              20   +0.0412   +1.2984 V-a   +0.0000
              21   +0.0309   -0.2528 V-a   +0.0000


PE: 31
    1.000 Error Factor
   -0.612 Sum            -0.612 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.8653   +0.3475 V-a   +0.0000
              14   +0.0478   +0.9209 V-a   +0.0000
              15   +0.0229   +1.2903 V-a   +0.0000
              16   +0.0679   -0.1473 V-a   +0.0000
              17   +0.9987   -0.7057 V-a   +0.0000
              18   +1.0000   -0.2001 V-a   +0.0000
              19   +0.0442   -0.6168 V-a   +0.0000
              20   +0.0412   -1.9810 V-a   +0.0000
              21   +0.0309   +1.2255 V-a   +0.0000


PE: 32
    1.000 Error Factor
    3.209 Sum             3.209 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13   +0.8653   +0.1056 V-a   -0.0622
              14   +0.0478   +0.1066 V-a   -0.0633
              15   +0.0229   +0.0989 V-a   -0.0591
              16   +0.0679   +0.1142 V-a   -0.0679
              17   +0.9987   +0.1103 V-a   -0.0672
              18   +1.0000   +2.9776 V-a   -1.7879
              19   +0.0442   +0.2683 V-a   -0.1596
              20   +0.0412   +0.0147 V-a   -0.0087
              21   +0.0309   +0.0653 V-a   -0.0386
```

```
PE: 33
    1.000 Error Factor
    0.381 Sum             0.381 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13   +0.8653   +1.0015 V-a   +0.0000
              14   +0.0478   +0.8265 V-a   +0.0000
              15   +0.0229   +1.5203 V-a   +0.0000
              16   +0.0679   -0.9609 V-a   +0.0000
              17   +0.9987   -0.0874 V-a   +0.0000
              18   +1.0000   -0.3454 V-a   +0.0000
              19   +0.0442   +0.4272 V-a   +0.0000
              20   +0.0412   -1.9415 V-a   +0.0000
              21   +0.0309   -0.0250 V-a   +0.0000


PE: 34
    1.000 Error Factor
    3.057 Sum             3.057 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.8653   +0.0083 V-a   -0.0066
              14   +0.0478   +0.0005 V-a   -0.0006
              15   +0.0229   +0.0137 V-a   -0.0092
              16   +0.0679   +0.0006 V-a   -0.0007
              17   +0.9987   +0.0493 V-a   -0.0351
              18   +1.0000   +2.9995 V-a   -1.8081
              19   +0.0442   +0.0200 V-a   -0.0139
              20   +0.0412   +0.0000 V-a   -0.0000
              21   +0.0309   +0.0001 V-a   -0.0002


PE: 35
    1.000 Error Factor
    2.510 Sum             2.510 Transfer          0.000 Output
        9 Weights        -0.004 Error            -0.004 Cumulative Error
              13   +0.8653   +1.2001 V-a   -0.1947
              14   +0.0478   +1.2041 V-a   -0.1992
              15   +0.0229   +0.0486 V-a   +0.0000
              16   +0.0679   +1.2001 V-a   -0.1937
              17   +0.9987   +0.0042 V-a   -0.0075
              18   +1.0000   +1.2161 V-a   -0.2115
              19   +0.0442   +0.5397 V-a   +0.0457
              20   +0.0412   +1.1995 V-a   -0.1972
              21   +0.0309   +1.2076 V-a   -0.2038


PE: 36
    1.000 Error Factor
    1.345 Sum             1.345 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13   +0.8653   +0.4745 V-a   +0.0000
              14   +0.0478   -1.1445 V-a   +0.0000
              15   +0.0229   +0.6977 V-a   +0.0000
              16   +0.0679   -0.8285 V-a   +0.0000
              17   +0.9987   +1.3465 V-a   +0.0000
              18   +1.0000   -0.2571 V-a   +0.0000
              19   +0.0442   -1.2002 V-a   +0.0000
              20   +0.0412   -1.1106 V-a   +0.0000
              21   +0.0309   +1.3187 V-a   +0.0000
```

```
PE: 37
    1.000 Error Factor
    0.040 Sum              0.040 Transfer          0.000 Output
        9 Weights          0.000 Error             0.000 Cumulative Error
              13   +0.8653   +0.1584 V-a   +0.0000
              14   +0.0478   +0.8957 V-a   +0.0000
              15   +0.0229   +1.3331 V-a   +0.0000
              16   +0.0679   -1.5082 V-a   +0.0000
              17   +0.9987   +0.8711 V-a   +0.0000
              18   +1.0000   -0.8345 V-a   +0.0000
              19   +0.0442   -0.6464 V-a   +0.0000
              20   +0.0412   -0.9710 V-a   +0.0000
              21   +0.0309   -1.1425 V-a   +0.0000


PE: 38
    1.000 Error Factor
   -2.995 Sum             -2.995 Transfer          0.000 Output
        9 Weights          0.000 Error             0.000 Cumulative Error
              13   +0.8653   -0.8723 V-a   +0.0000
              14   +0.0478   -0.3769 V-a   +0.0000
              15   +0.0229   +0.1054 V-a   +0.0000
              16   +0.0679   +0.1327 V-a   +0.0000
              17   +0.9987   -1.5604 V-a   +0.0000
              18   +1.0000   -0.6819 V-a   +0.0000
              19   +0.0442   +1.5674 V-a   +0.0000
              20   +0.0412   -0.3175 V-a   +0.0000
              21   +0.0309   -1.6158 V-a   +0.0000


PE: 39
    1.000 Error Factor
    4.982 Sum              4.982 Transfer          1.000 Output
        9 Weights          0.005 Error             0.005 Cumulative Error
              13   +0.8653   +1.5643 V-a   -0.6342
              14   +0.0478   +0.0865 V-a   -0.0351
              15   +0.0229   +0.0417 V-a   -0.0185
              16   +0.0679   +0.1228 V-a   -0.0500
              17   +0.9987   +1.8035 V-a   -0.7220
              18   +1.0000   +1.8058 V-a   -0.7227
              19   +0.0442   +0.0805 V-a   -0.0356
              20   +0.0412   +0.0751 V-a   -0.0337
              21   +0.0309   +0.0559 V-a   -0.0230


Layer: output
       PEs: 3                                        Sum: Sum
   Spacing: 5         F' minimum: 0.00          Transfer: Sigmoid
     Shape: Square                                Output: Direct
     Scale: 1.00       Low Limit: -9999.00    Error Func: Standard
    Offset: 0.00      High Limit: 9999.00          Learn: Cum-Delta-Rule
  Init Low: -0.100     Init High: 0.100      L/R Schedule: (Network)
  Winner 1: None                                Winner 2: None
```

```
PE: 29
    1.000 Error Factor
   -3.653 Sum             0.025 Transfer          0.025 Output
       16 Weights        -0.001 Error            -0.025 Cumulative Error
               22   +0.0000   -0.0846 V-a   +0.0000
               23   +0.0000   +0.0202 V-a   +0.0000
               24   +0.0000   +0.0864 V-a   +0.0000
               25   +0.0000   +0.0954 V-a   +0.0000
               26   +0.0000   -0.0702 V-a   +0.0000
               27   +0.0000   +0.0408 V-a   +0.0000
               28   +0.0000   +0.0764 V-a   +0.0000
               31   +0.0000   -0.0618 V-a   +0.0000
               32   +0.0000   -3.7300 V-a   +0.0000
               33   +0.0000   -0.0744 V-a   +0.0000
               34   +0.0000   -4.0519 V-a   +0.0000
               35   +0.0000   +3.3849 V-a   +0.0000
               36   +0.0000   -0.0438 V-a   +0.0000
               37   +0.0000   +0.0465 V-a   +0.0000
               38   +0.0000   -0.0879 V-a   +0.0000
               39   +1.0000   -3.6533 V-a   -0.0006
PE: 30
    1.000 Error Factor
    3.653 Sum             0.975 Transfer          0.975 Output
       16 Weights         0.001 Error             0.025 Cumulative Error
               22   +0.0000   -0.0456 V-a   +0.0000
               23   +0.0000   -0.0818 V-a   +0.0000
               24   +0.0000   -0.0785 V-a   +0.0000
               25   +0.0000   -0.0513 V-a   +0.0000
               26   +0.0000   -0.0008 V-a   +0.0000
               27   +0.0000   -0.0756 V-a   +0.0000
               28   +0.0000   -0.0580 V-a   +0.0000
               31   +0.0000   -0.0864 V-a   +0.0000
               32   +0.0000   -2.5838 V-a   +0.0000
               33   +0.0000   -0.0692 V-a   +0.0000
               34   +0.0000   -3.9098 V-a   +0.0000
               35   +0.0000   -3.3849 V-a   +0.0000
               36   +0.0000   +0.0618 V-a   +0.0000
               37   +0.0000   +0.0499 V-a   +0.0000
               38   +0.0000   -0.0083 V-a   +0.0000
               39   +1.0000   +3.6532 V-a   +0.0006
PE: 40
    1.000 Error Factor
   -4.510 Sum             0.011 Transfer          0.011 Output
       16 Weights        -0.000 Error            -0.011 Cumulative Error
               22   +0.0000   -0.0299 V-a   +0.0000
               23   +0.0000   -0.0219 V-a   +0.0000
               24   +0.0000   +0.0725 V-a   +0.0000
               25   +0.0000   -0.0001 V-a   +0.0000
               26   +0.0000   -0.0811 V-a   +0.0000
               27   +0.0000   +0.0489 V-a   +0.0000
               28   +0.0000   +0.0381 V-a   +0.0000
               31   +0.0000   +0.0126 V-a   +0.0000
               32   +0.0000   +2.5391 V-a   +0.0000
               33   +0.0000   -0.0630 V-a   +0.0000
               34   +0.0000   +3.9085 V-a   +0.0000
               35   +0.0000   -4.3577 V-a   +0.0000
               36   +0.0000   +0.0835 V-a   +0.0000
               37   +0.0000   -0.0406 V-a   +0.0000
               38   +0.0000   +0.0933 V-a   +0.0000
               39   +1.0000   -4.5098 V-a   -0.0001
```

E. Three Output Back-Propagation/Kohenan Network (18 Element)

```
              Type: Hetero-Associative        Learn Data: Alpha (pat2)
      Display Mode: Network                  Recall Data: Alpha (ad31a)
     Display Style: default                     User I/O: userio
  Control Strategy: backprop                L/R Schedule: backprop
      10001 Learn              0 Recall                0 Layer
         10 Aux 1              0 Aux 2                 0 Aux 3
L/R Schedule: backprop
   Recall Step                1          0          0          0          0
     Input Clamp         0.0000     0.0000     0.0000     0.0000     0.0000
     Firing Density    100.0000     0.0000     0.0000     0.0000     0.0000
     Temperature         0.0000     0.0000     0.0000     0.0000     0.0000
     Gain                1.0000     0.0000     0.0000     0.0000     0.0000
     Modifier            1.0000     0.0000     0.0000     0.0000     0.0000
   Learn Step              5000          0          0          0          0
     Coefficient 1       0.9000     0.0000     0.0000     0.0000     0.0000
     Coefficient 2       0.6000     0.0000     0.0000     0.0000     0.0000
     Coefficient 3       0.0000     0.0000     0.0000     0.0000     0.0000
     Temperature         0.0000     0.0000     0.0000     0.0000     0.0000
Layer: 1
       PEs: 1                                          Sum: Sum
    Spacing: 5       F' minimum: 0.00             Transfer: Linear
      Shape: Square                                 Output: Direct
      Scale: 1.00     Low Limit: 0.00           Error Func: Standard
     Offset: 0.00    High Limit: 9999.00             Learn: --None--
   Init Low: -0.100   Init High: 0.100        L/R Schedule: (Network)
   Winner 1: None                                 Winner 2: None
   PE: Bias
       1.000 Error Factor
       0.000 Sum             1.000 Transfer           1.000 Output
           0 Weights         5.274 Error              0.000 Cumulative Error
Layer: In
       PEs: 11                                         Sum: Sum
    Spacing: 5       F' minimum: 0.00             Transfer: Linear
      Shape: Square                                 Output: Direct
      Scale: 1.00     Low Limit: -9999.00       Error Func: Standard
     Offset: 0.00    High Limit: 9999.00             Learn: --None--
   Init Low: -0.100   Init High: 0.100        L/R Schedule: (Network)
   Winner 1: None                                 Winner 2: None
   PE: 2
       1.000 Error Factor
       0.755 Sum             0.755 Transfer           0.755 Output
           0 Weights         0.002 Error              0.000 Cumulative Error
   PE: 3
       1.000 Error Factor
       0.660 Sum             0.660 Transfer           0.660 Output
           0 Weights         0.000 Error              0.000 Cumulative Error
   PE: 4
       1.000 Error Factor
       0.560 Sum             0.560 Transfer           0.560 Output
           0 Weights        -0.000 Error              0.000 Cumulative Error
   PE: 5
       1.000 Error Factor
       0.790 Sum             0.790 Transfer           0.790 Output
           0 Weights        -0.000 Error              0.000 Cumulative Error
   PE: 6
       1.000 Error Factor
       0.818 Sum             0.818 Transfer           0.818 Output
           0 Weights         0.002 Error              0.000 Cumulative Error
   PE: 7
       1.000 Error Factor
```

```
      0.990 Sum             0.990 Transfer          0.990 Output
          0 Weights         0.003 Error             0.000 Cumulative Error
  PE: 8
      1.000 Error Factor
      0.980 Sum             0.980 Transfer          0.980 Output
          0 Weights         0.003 Error             0.000 Cumulative Error
  PE: 9
      1.000 Error Factor
      0.375 Sum             0.375 Transfer          0.375 Output
          0 Weights         0.000 Error             0.000 Cumulative Error
  PE: 10
      1.000 Error Factor
      0.300 Sum             0.300 Transfer          0.300 Output
          0 Weights        -0.000 Error             0.000 Cumulative Error
  PE: 11
      1.000 Error Factor
      0.300 Sum             0.300 Transfer          0.300 Output
          0 Weights        -0.001 Error             0.000 Cumulative Error
  PE: 12
      1.000 Error Factor
      0.862 Sum             0.862 Transfer          0.862 Output
          0 Weights        -0.002 Error             0.000 Cumulative Error
Layer: Hidden 1
       PEs: 9                                            Sum: Sum
   Spacing: 5        F' minimum: 0.00               Transfer: Sigmoid
     Shape: Square                                    Output: Direct
     Scale: 1.00      Low Limit: -9999.00         Error Func: Standard
    Offset: 0.00     High Limit: 9999.00               Learn: Cum-Delta-Rule
  Init Low: -0.100    Init High: 0.100          L/R Schedule: (Network)
  Winner 1: None                                    Winner 2: None
  PE: 13
      1.000 Error Factor
      4.861 Sum             0.992 Transfer          0.992 Output
         12 Weights         0.000 Error             0.013 Cumulative Error
               Bias   +1.0000   -1.0342 V-a   +0.0001
                  2   +0.7548   +1.2374 V-a   +0.0001
                  3   +0.6600   +0.5652 V-a   +0.0001
                  4   +0.5600   +0.5555 V-a   +0.0001
                  5   +0.7900   -0.3872 V-a   +0.0001
                  6   +0.8180   +1.3907 V-a   +0.0001
                  7   +0.9902   +1.8990 V-a   +0.0001
                  8   +0.9800   +1.7858 V-a   +0.0001
                  9   +0.3750   +0.5242 V-a   +0.0000
                 10   +0.3000   +0.1026 V-a   +0.0000
                 11   +0.3000   +0.2388 V-a   +0.0000
                 12   +0.8615   -0.5614 V-a   +0.0001
  PE: 14
      1.000 Error Factor
     -4.636 Sum             0.010 Transfer          0.010 Output
         12 Weights        -0.000 Error            -0.002 Cumulative Error
               Bias   +1.0000   -1.6236 V-a   -0.0000
                  2   +0.7548   -0.1610 V-a   -0.0000
                  3   +0.6600   -0.4453 V-a   -0.0000
                  4   +0.5600   -0.2987 V-a   -0.0000
                  5   +0.7900   -0.5126 V-a   -0.0000
                  6   +0.8180   -0.4674 V-a   -0.0000
                  7   +0.9902   -0.4215 V-a   -0.0000
                  8   +0.9800   -0.7467 V-a   -0.0000
                  9   +0.3750   -0.3815 V-a   -0.0000
                 10   +0.3000   -0.4979 V-a   -0.0000
                 11   +0.3000   -0.7253 V-a   -0.0000
                 12   +0.8615   +0.0199 V-a   -0.0000
```

```
PE: 15
    1.000 Error Factor
   -4.618 Sum              0.010 Transfer          0.010 Output
       12 Weights         -0.000 Error            -0.001 Cumulative Error
            Bias  +1.0000  -1.8120 V-a  -0.0000
               2  +0.7548  -0.1929 V-a  -0.0000
               3  +0.6600  -0.5622 V-a  -0.0000
               4  +0.5600  -0.2718 V-a  -0.0000
               5  +0.7900  -0.4892 V-a  -0.0000
               6  +0.8180  -0.5074 V-a  -0.0000
               7  +0.9902  -0.3752 V-a  -0.0000
               8  +0.9800  -0.5238 V-a  -0.0000
               9  +0.3750  -0.3914 V-a  -0.0000
              10  +0.3000  -0.2927 V-a  -0.0000
              11  +0.3000  -0.7769 V-a  -0.0000
              12  +0.8615  +0.0193 V-a  -0.0000
PE: 16
    1.000 Error Factor
   -4.415 Sum              0.012 Transfer          0.012 Output
       12 Weights         -0.000 Error            -0.004 Cumulative Error
            Bias  +1.0000  -0.9037 V-a  -0.0000
               2  +0.7548  -0.2500 V-a  -0.0000
               3  +0.6600  -0.3098 V-a  -0.0000
               4  +0.5600  -0.4876 V-a  -0.0000
               5  +0.7900  -0.2583 V-a  -0.0000
               6  +0.8180  -0.7231 V-a  -0.0000
               7  +0.9902  -0.7582 V-a  -0.0000
               8  +0.9800  -0.9290 V-a  -0.0000
               9  +0.3750  -0.2874 V-a  -0.0000
              10  +0.3000  -0.2977 V-a  -0.0000
              11  +0.3000  -0.5774 V-a  -0.0000
              12  +0.8615  -0.0212 V-a  -0.0000
PE: 17
    1.000 Error Factor
    3.326 Sum              0.965 Transfer          0.965 Output
       12 Weights          0.001 Error             0.019 Cumulative Error
            Bias  +1.0000  -3.1112 V-a  +0.0006
               2  +0.7548  +1.7292 V-a  +0.0004
               3  +0.6600  +0.2074 V-a  +0.0004
               4  +0.5600  -0.0464 V-a  +0.0003
               5  +0.7900  -0.5956 V-a  +0.0004
               6  +0.8180  +1.7247 V-a  +0.0005
               7  +0.9902  +3.0446 V-a  +0.0006
               8  +0.9800  +2.2436 V-a  +0.0005
               9  +0.3750  +0.0418 V-a  +0.0002
              10  +0.3000  -0.2145 V-a  +0.0002
              11  +0.3000  -1.1045 V-a  +0.0002
              12  +0.8615  -0.8737 V-a  +0.0005
PE: 18
    1.000 Error Factor
   -4.612 Sum              0.010 Transfer          0.010 Output
       12 Weights         -0.000 Error            -0.004 Cumulative Error
            Bias  +1.0000  -1.0474 V-a  -0.0000
               2  +0.7548  -0.3453 V-a  -0.0000
               3  +0.6600  -0.3940 V-a  -0.0000
               4  +0.5600  -0.4069 V-a  -0.0000
               5  +0.7900  -0.3718 V-a  -0.0000
               6  +0.8180  -0.7261 V-a  -0.0000
               7  +0.9902  -0.6754 V-a  -0.0000
               8  +0.9800  -0.9476 V-a  -0.0000
               9  +0.3750  -0.4416 V-a  -0.0000
              10  +0.3000  -0.3153 V-a  -0.0000
              11  +0.3000  -0.5997 V-a  -0.0000
              12  +0.8615  +0.1267 V-a  -0.0000
```

```
PE: 19
    1.000 Error Factor
   -5.495 Sum              0.004 Transfer          0.004 Output
       12 Weights         -0.000 Error            -0.024 Cumulative Error
            Bias   +1.0000   +2.1916 V-a   -0.0001
               2   +0.7548   -2.9498 V-a   -0.0001
               3   +0.6600   -1.0705 V-a   -0.0001
               4   +0.5600   +0.7463 V-a   -0.0000
               5   +0.7900   +0.3166 V-a   -0.0001
               6   +0.8180   -2.6618 V-a   -0.0001
               7   +0.9902   -4.8158 V-a   -0.0001
               8   +0.9800   -3.7422 V-a   -0.0001
               9   +0.3750   -0.5635 V-a   -0.0000
              10   +0.3000   +0.9467 V-a   -0.0000
              11   +0.3000   +2.3746 V-a   -0.0000
              12   +0.8615   +5.1155 V-a   -0.0001


PE: 20
    1.000 Error Factor
   -4.876 Sum              0.008 Transfer          0.008 Output
       12 Weights         -0.000 Error            -0.023 Cumulative Error
            Bias   +1.0000   +2.4922 V-a   -0.0002
               2   +0.7548   -2.5127 V-a   -0.0001
               3   +0.6600   -0.7890 V-a   -0.0001
               4   +0.5600   +0.6404 V-a   -0.0001
               5   +0.7900   +0.3751 V-a   -0.0001
               6   +0.8180   -2.4969 V-a   -0.0001
               7   +0.9902   -4.4508 V-a   -0.0002
               8   +0.9800   -3.3283 V-a   -0.0002
               9   +0.3750   -0.3295 V-a   -0.0001
              10   +0.3000   +0.7250 V-a   -0.0000
              11   +0.3000   +1.9802 V-a   -0.0000
              12   +0.8615   +3.9668 V-a   -0.0001


PE: 21
    1.000 Error Factor
    6.552 Sum              0.999 Transfer          0.999 Output
       12 Weights          0.000 Error             0.002 Cumulative Error
            Bias   +1.0000   -4.1503 V-a   +0.0000
               2   +0.7548   -0.1703 V-a   +0.0000
               3   +0.6600   -1.2784 V-a   +0.0000
               4   +0.5600   +1.8437 V-a   +0.0000
               5   +0.7900   -1.5246 V-a   +0.0000
               6   +0.8180   +1.8831 V-a   +0.0000
               7   +0.9902   +1.8289 V-a   +0.0000
               8   +0.9800   +2.6773 V-a   +0.0000
               9   +0.3750   -2.7910 V-a   +0.0000
              10   +0.3000   -1.7110 V-a   +0.0000
              11   +0.3000   -2.7594 V-a   +0.0000
              12   +0.8615   +9.5874 V-a   +0.0000


Layer: Layer
       PEs: 18                                      Sum: Sum
   Spacing: 5        F' minimum: 0.00          Transfer: Linear
     Shape: Square                               Output: One-Highest
     Scale: 1.00      Low Limit: -9999.00    Error Func: Standard
    Offset: 0.00     High Limit: 9999.00          Learn: KohonenN
  Init Low: -0.100    Init High: 0.100      L/R Schedule: (Network)
  Winner 1: None                               Winner 2: None
```

```
PE: 22
    1.000 Error Factor
    1.614 Sum             1.614 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13    +0.9923    -0.2697 V-a    +0.0000
              14    +0.0096    -0.0333 V-a    +0.0000
              15    +0.0098    -0.6645 V-a    +0.0000
              16    +0.0119    -0.9586 V-a    +0.0000
              17    +0.9653    +1.3023 V-a    +0.0000
              18    +0.0098    -1.4475 V-a    +0.0000
              19    +0.0041    -1.2689 V-a    +0.0000
              20    +0.0076    +1.3183 V-a    +0.0000
              21    +0.9986    +0.6530 V-a    +0.0000


PE: 23
    1.000 Error Factor
   -3.512 Sum            -3.512 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13    +0.9923    -0.5673 V-a    +0.0000
              14    +0.0096    +1.0559 V-a    +0.0000
              15    +0.0098    -0.1340 V-a    +0.0000
              16    +0.0119    +1.3033 V-a    +0.0000
              17    +0.9653    -1.6732 V-a    +0.0000
              18    +0.0098    -0.6358 V-a    +0.0000
              19    +0.0041    +0.6337 V-a    +0.0000
              20    +0.0076    +0.6222 V-a    +0.0000
              21    +0.9986    -1.3618 V-a    +0.0000


PE: 24
    1.000 Error Factor
    2.799 Sum             2.799 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13    +0.9923    +0.8240 V-a    +0.0000
              14    +0.0096    +0.6789 V-a    +0.0000
              15    +0.0098    +0.5208 V-a    +0.0000
              16    +0.0119    -0.6663 V-a    +0.0000
              17    +0.9653    +1.1351 V-a    +0.0000
              18    +0.0098    -0.5948 V-a    +0.0000
              19    +0.0041    -1.8063 V-a    +0.0000
              20    +0.0076    +1.2052 V-a    +0.0000
              21    +0.9986    +0.8874 V-a    +0.0000


PE: 25
    1.000 Error Factor
    0.287 Sum             0.287 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13    +0.9923    -1.2541 V-a    +0.0000
              14    +0.0096    -0.8044 V-a    +0.0000
              15    +0.0098    -0.2755 V-a    +0.0000
              16    +0.0119    +1.5212 V-a    +0.0000
              17    +0.9653    +0.4578 V-a    +0.0000
              18    +0.0098    +1.2366 V-a    +0.0000
              19    +0.0041    -0.7290 V-a    +0.0000
              20    +0.0076    +0.9915 V-a    +0.0000
              21    +0.9986    +1.0663 V-a    +0.0000
```

```
PE: 26
    1.000 Error Factor
   -1.149 Sum            -1.149 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13    +0.9923    -0.7714 V-a   +0.0000
              14    +0.0096    +1.2962 V-a   +0.0000
              15    +0.0098    +0.9884 V-a   +0.0000
              16    +0.0119    +1.6520 V-a   +0.0000
              17    +0.9653    -0.8852 V-a   +0.0000
              18    +0.0098    +0.2536 V-a   +0.0000
              19    +0.0041    -0.1432 V-a   +0.0000
              20    +0.0076    -1.3994 V-a   +0.0000
              21    +0.9986    +0.4380 V-a   +0.0000


PE: 27
    1.000 Error Factor
    3.696 Sum             3.696 Transfer          0.000 Output
        9 Weights        -0.003 Error            -0.003 Cumulative Error
              13    +0.9923    +0.0566 V-a   -0.0489
              14    +0.0096    +0.0365 V-a   -0.0416
              15    +0.0098    +0.0424 V-a   -0.0450
              16    +0.0119    +0.0358 V-a   -0.0423
              17    +0.9653    +0.7726 V-a   -0.4425
              18    +0.0098    +0.0348 V-a   -0.0426
              19    +0.0041    +0.0537 V-a   -0.1427
              20    +0.0076    +0.0535 V-a   -0.1148
              21    +0.9986    +2.8963 V-a   -1.7289


PE: 28
    1.000 Error Factor
   -0.711 Sum            -0.711 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13    +0.9923    +1.1487 V-a   +0.0000
              14    +0.0096    +1.1453 V-a   +0.0000
              15    +0.0098    -0.2200 V-a   +0.0000
              16    +0.0119    +0.2640 V-a   +0.0000
              17    +0.9653    -1.3871 V-a   +0.0000
              18    +0.0098    +0.4516 V-a   +0.0000
              19    +0.0041    -1.3839 V-a   +0.0000
              20    +0.0076    +1.3866 V-a   +0.0000
              21    +0.9986    -0.5335 V-a   +0.0000


PE: 31
    1.000 Error Factor
    0.622 Sum             0.622 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13    +0.9923    +1.4318 V-a   +0.0000
              14    +0.0096    -0.8485 V-a   +0.0000
              15    +0.0098    -1.3099 V-a   +0.0000
              16    +0.0119    +0.8818 V-a   +0.0000
              17    +0.9653    +0.1057 V-a   +0.0000
              18    +0.0098    -1.7106 V-a   +0.0000
              19    +0.0041    +0.1564 V-a   +0.0000
              20    +0.0076    +0.0806 V-a   +0.0000
              21    +0.9986    -0.8764 V-a   +0.0000
```

```
PE: 32
    1.000 Error Factor
   -0.338 Sum            -0.338 Transfer          0.000 Output
        9 Weights         0.000 Error             0.000 Cumulative Error
              13   +0.9923   -1.1688 V-a   +0.0000
              14   +0.0096   +1.4759 V-a   +0.0000
              15   +0.0098   -0.5085 V-a   +0.0000
              16   +0.0119   +0.7703 V-a   +0.0000
              17   +0.9653   +0.8245 V-a   +0.0000
              18   +0.0098   -1.2744 V-a   +0.0000
              19   +0.0041   -1.3940 V-a   +0.0000
              20   +0.0076   +0.5968 V-a   +0.0000
              21   +0.9986   +0.0217 V-a   +0.0000


PE: 33
    1.000 Error Factor
   -0.535 Sum            -0.535 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.9923   +1.5136 V-a   +0.0000
              14   +0.0096   -0.8522 V-a   +0.0000
              15   +0.0098   -0.6560 V-a   +0.0000
              16   +0.0119   +0.4855 V-a   +0.0000
              17   +0.9653   -1.1323 V-a   +0.0000
              18   +0.0098   -0.9398 V-a   +0.0000
              19   +0.0041   -1.3269 V-a   +0.0000
              20   +0.0076   +0.7291 V-a   +0.0000
              21   +0.9986   -0.9269 V-a   +0.0000


PE: 34
    1.000 Error Factor
    5.108 Sum             5.108 Transfer          1.000 Output
        9 Weights         0.014 Error             0.014 Cumulative Error
              13   +0.9923   +1.7476 V-a   -0.6932
              14   +0.0096   +0.0203 V-a   -0.0251
              15   +0.0098   +0.0201 V-a   -0.0230
              16   +0.0119   +0.0255 V-a   -0.0327
              17   +0.9653   +1.6797 V-a   -0.5629
              18   +0.0098   +0.0214 V-a   -0.0296
              19   +0.0041   +0.0248 V-a   -0.0997
              20   +0.0076   +0.0347 V-a   -0.1228
              21   +0.9986   +1.7666 V-a   -0.7417


PE: 35
    1.000 Error Factor
   -3.426 Sum            -3.426 Transfer          0.000 Output
        9 Weights        -0.000 Error            -0.000 Cumulative Error
              13   +0.9923   -1.0899 V-a   +0.0000
              14   +0.0096   +1.5487 V-a   +0.0000
              15   +0.0098   +0.0439 V-a   +0.0000
              16   +0.0119   -0.1950 V-a   +0.0000
              17   +0.9653   -1.5750 V-a   +0.0000
              18   +0.0098   -0.0271 V-a   +0.0000
              19   +0.0041   +0.9924 V-a   +0.0000
              20   +0.0076   +1.0886 V-a   +0.0000
              21   +0.9986   -0.8500 V-a   +0.0000
```

```
PE: 36
    1.000 Error Factor
    1.769 Sum            1.769 Transfer          0.000 Output
        9 Weights       -0.000 Error            -0.000 Cumulative Error
              13    +0.9923    +1.2615 V-a    +0.0000
              14    +0.0096    +1.2208 V-a    +0.0000
              15    +0.0098    +1.5706 V-a    +0.0000
              16    +0.0119    -0.4419 V-a    +0.0000
              17    +0.9653    +1.1629 V-a    +0.0000
              18    +0.0098    -1.0973 V-a    +0.0000
              19    +0.0041    +0.5620 V-a    +0.0000
              20    +0.0076    -0.0292 V-a    +0.0000
              21    +0.9986    -0.6189 V-a    +0.0000


PE: 37
    1.000 Error Factor
    0.347 Sum            0.347 Transfer          0.000 Output
        9 Weights       -0.000 Error            -0.000 Cumulative Error
              13    +0.9923    +1.2758 V-a    +0.0000
              14    +0.0096    +0.2388 V-a    +0.0000
              15    +0.0098    -1.5708 V-a    +0.0000
              16    +0.0119    -1.5253 V-a    +0.0000
              17    +0.9653    -0.6843 V-a    +0.0000
              18    +0.0098    +1.0265 V-a    +0.0000
              19    +0.0041    -0.8227 V-a    +0.0000
              20    +0.0076    -0.5191 V-a    +0.0000
              21    +0.9986    -0.2304 V-a    +0.0000


PE: 39
    1.000 Error Factor
    2.068 Sum            2.068 Transfer          0.000 Output
        9 Weights       -0.013 Error            -0.013 Cumulative Error
              13    +0.9923    +0.8356 V-a    -0.0835
              14    +0.0096    +0.1782 V-a    -0.1281
              15    +0.0098    +0.1520 V-a    -0.1068
              16    +0.0119    +0.3269 V-a    -0.2762
              17    +0.9653    +0.1257 V-a    +0.0195
              18    +0.0098    +0.2913 V-a    -0.2485
              19    +0.0041    +1.8487 V-a    -0.9781
              20    +0.0076    +1.8544 V-a    -0.9705
              21    +0.9986    +1.0876 V-a    +0.2675


PE: 40
    1.000 Error Factor
    4.205 Sum            4.205 Transfer          0.000 Output
        9 Weights        0.000 Error             0.000 Cumulative Error
              13    +0.9923    +2.1414 V-a    -1.0350
              14    +0.0096    +0.0123 V-a    -0.0073
              15    +0.0098    +0.0118 V-a    -0.0074
              16    +0.0119    +0.0166 V-a    -0.0109
              17    +0.9653    +2.1003 V-a    -1.0016
              18    +0.0098    +0.0111 V-a    -0.0076
              19    +0.0041    +0.0002 V-a    -0.0003
              20    +0.0076    +0.0011 V-a    -0.0012
              21    +0.9986    +0.0526 V-a    -0.0262
```

```
PE: 41
    1.000 Error Factor
    0.036 Sum              0.036 Transfer          0.000 Output
        9 Weights         -0.000 Error            -0.000 Cumulative Error
              13   +0.9923   -1.5728 V-a   +0.0000
              14   +0.0096   +1.4243 V-a   +0.0000
              15   +0.0098   +1.2636 V-a   +0.0000
              16   +0.0119   -0.2533 V-a   +0.0000
              17   +0.9653   +0.8588 V-a   +0.0000
              18   +0.0098   -0.5139 V-a   +0.0000
              19   +0.0041   -0.0328 V-a   +0.0000
              20   +0.0076   +1.1325 V-a   +0.0000
              21   +0.9986   +0.7426 V-a   +0.0000


PE: 42
    1.000 Error Factor
   -0.664 Sum             -0.664 Transfer          0.000 Output
        9 Weights         -0.000 Error            -0.000 Cumulative Error
              13   +0.9923   -0.8068 V-a   +0.0000
              14   +0.0096   -1.7099 V-a   +0.0000
              15   +0.0098   -1.7416 V-a   +0.0000
              16   +0.0119   +0.8137 V-a   +0.0000
              17   +0.9653   +0.9975 V-a   +0.0000
              18   +0.0098   +0.2314 V-a   +0.0000
              19   +0.0041   +0.1672 V-a   +0.0000
              20   +0.0076   -0.0636 V-a   +0.0000
              21   +0.9986   -0.8059 V-a   +0.0000


Layer: Layer
      PEs: 3                                      Sum: Sum
  Spacing: 5         F' minimum: 0.00        Transfer: Sigmoid
    Shape: Square                              Output: Direct
    Scale: 1.00       Low Limit: -9999.00  Error Func: Standard
   Offset: 0.00      High Limit: 9999.00        Learn: Cum-Delta-Rule
 Init Low: -0.100     Init High: 0.100    L/R Schedule: (Network)
 Winner 1: None                              Winner 2: None


PE: 29
    1.000 Error Factor
   -2.990 Sum              0.048 Transfer          0.048 Output
       18 Weights         -0.002 Error            -0.048 Cumulative Error
              22   +0.0000   -0.0384 V-a   +0.0000
              23   +0.0000   +0.0422 V-a   +0.0000
              24   +0.0000   -0.0098 V-a   +0.0000
              25   +0.0000   -0.0746 V-a   +0.0000
              26   +0.0000   -0.0138 V-a   +0.0000
              27   +0.0000   -0.2739 V-a   +0.0000
              28   +0.0000   +0.0506 V-a   +0.0000
              31   +0.0000   -0.0177 V-a   +0.0000
              32   +0.0000   -0.0582 V-a   +0.0000
              33   +0.0000   -0.0536 V-a   +0.0000
              34   +1.0000   -2.9904 V-a   -0.0020
              35   +0.0000   -0.0215 V-a   +0.0000
              36   +0.0000   +0.0095 V-a   +0.0000
              37   +0.0000   -0.0071 V-a   +0.0000
              39   +0.0000   +3.2139 V-a   +0.0000
              40   +0.0000   -3.7853 V-a   +0.0000
              41   +0.0000   +0.0805 V-a   +0.0000
              42   +0.0000   +0.0895 V-a   +0.0000
```

PE: 30

1.000 Error Factor				
2.990 Sum		0.952 Transfer		0.952 Output
18 Weights		0.002 Error		0.048 Cumulative Error
22	+0.0000	+0.0460 V-a	+0.0000	
23	+0.0000	-0.0211 V-a	+0.0000	
24	+0.0000	+0.0446 V-a	+0.0000	
25	+0.0000	-0.0179 V-a	+0.0000	
26	+0.0000	+0.0357 V-a	+0.0000	
27	+0.0000	-1.9681 V-a	+0.0000	
28	+0.0000	-0.0113 V-a	+0.0000	
31	+0.0000	-0.0207 V-a	+0.0000	
32	+0.0000	+0.0064 V-a	+0.0000	
33	+0.0000	-0.0989 V-a	+0.0000	
34	+1.0000	+2.9901 V-a	+0.0020	
35	+0.0000	-0.0970 V-a	+0.0000	
36	+0.0000	-0.0421 V-a	+0.0000	
37	+0.0000	-0.0502 V-a	+0.0000	
39	+0.0000	-3.2143 V-a	+0.0000	
40	+0.0000	-3.4471 V-a	+0.0000	
41	+0.0000	-0.0248 V-a	+0.0000	
42	+0.0000	-0.0687 V-a	+0.0000	

PE: 38

1.000 Error Factor				
-4.419 Sum		0.012 Transfer		0.012 Output
18 Weights		-0.000 Error		-0.012 Cumulative Error
22	+0.0000	-0.0725 V-a	+0.0000	
23	+0.0000	-0.0742 V-a	+0.0000	
24	+0.0000	+0.0136 V-a	+0.0000	
25	+0.0000	-0.0307 V-a	+0.0000	
26	+0.0000	-0.0278 V-a	+0.0000	
27	+0.0000	-2.2025 V-a	+0.0000	
28	+0.0000	+0.0478 V-a	+0.0000	
31	+0.0000	+0.0817 V-a	+0.0000	
32	+0.0000	-0.0242 V-a	+0.0000	
33	+0.0000	+0.0956 V-a	+0.0000	
34	+1.0000	-4.4190 V-a	-0.0001	
35	+0.0000	-0.0437 V-a	+0.0000	
36	+0.0000	+0.0851 V-a	+0.0000	
37	+0.0000	+0.0987 V-a	+0.0000	
39	+0.0000	-4.2026 V-a	+0.0000	
40	+0.0000	+3.4445 V-a	+0.0000	
41	+0.0000	-0.0192 V-a	+0.0000	
42	+0.0000	-0.0291 V-a	+0.0000	

APPENDIX D. PROGRAMMING FOR *NESTOR*

Program JOE.C is a modified PIF.C program from the *NESTOR* software package. The purpose of the program is to present data in four different formats by defining feature values and feature spaces. Terms used in the program are defined in the *NESTOR Reference Manual*.

```
/*================================================================*/
/*
   Functionality:
      This file contains the pattern input functions used as an example
      in chapter 4 of the NDS Users Guide.

   History:
      11/87, Ray Rimey, created.
      07/89, Joe Gengo, modified.
*/
/*================================================================*/ #include <stdio.h>
#include <string.h>
#include "nls_user.h"
/*================================================================*/
/* The current data file is stored in this global variable */
FILE *data_fp;
/* The current pattern is stored in this global variable */
typedef struct
   float f1;
   float f2;
   float f3;
   float f4;
   float f5;
   float f6;
   float f7;
   float f8;
   float f9;
   float f10;
   float f11;
} pattern_t;

pattern_t pattern;

/*================================================================*/
/* Open a new data file */
ERROR_CODE nls_open_data_file(data_filename)
    char data_filename[];
{
    extern FILE *data_fp;

    if ((data_fp = fopen(data_filename, "r")) == (FILE *) NULL)
       return((ERROR_CODE) open_error);

    return((ERROR_CODE) no_errors);
```

```
}

/*=============================================================*/
/* Close the data file */

ERROR_CODE nls_close_data_file()
{
   extern FILE *data_fp;

   if (fclose(data_fp) != 0)
      return((ERROR_CODE) close_error);
   else
      return((ERROR_CODE) no_errors);
}

/*=============================================================*/
/* Read a new pattern */

ERROR_CODE nls_pattern_read(record_n, real_class, valid_p)
   short record_n;
   CLASS_NAME real_class;
   BOOLEAN *valid_p;
{
   short record_index;   /* index of a pattern in the data file */
   int stat;             /* returned status value */

   extern FILE *data_fp;
   extern pattern_t pattern;

   /* The way we read the record_n'th pattern from the file is to
    * start from the beginning and read record_n patterns.
    */

   /* Move to the start of the file */
   if (fseek(data_fp, (long) 0, (int) 0) != 0)
      return((ERROR_CODE) seek_error);

   /* Read through the file to the record_n'th pattern */
   for (record_index = 1; record_index <= record_n; record_index++)
   {

     stat = fscanf(data_fp, "%f %f %f %f %f %f %f %f %f %f %f %s",
                   &pattern.f1, &pattern.f2, &pattern.f3,
                   &pattern.f4, &pattern.f5, &pattern.f6,
                   &pattern.f7, &pattern.f8, &pattern.f9,
                   &pattern.f10, &pattern.f11, real_class);
      if (stat == EOF)
         return((ERROR_CODE) end_of_file);
      else
      if (stat != 12)
         return((ERROR_CODE) read_error);
   }

   /* All patterns are valid */
   *valid_p = TRUE;

   return((ERROR_CODE) no_errors);
}

/*=============================================================*/
/* Encode the current pattern */

ERROR_CODE nls_pattern_encode(
      encoding_tag, fs_resolution, user_info, encode_status_p)
```

```
   char encoding_tag[];
   short fs_resolution;
   char user_info[];
   ENCODE_STATUS *encode_status_p;
{
   ERROR_CODE stat;      /* returned error code */

   ERROR_CODE encode1();
   ERROR_CODE encode2();
   ERROR_CODE encode3();
   ERROR_CODE encode4();

   /* ONE_THR */
   if (strcmp(encoding_tag, "ONE_THR") == 0)
   {
      stat = encode1(fs_resolution, user_info, encode_status_p);
      if (stat != (ERROR_CODE) no_errors)
         return(stat);
   }

   /* SUM_CODE */
   else
   if (strcmp(encoding_tag, "SUM_CODE") == 0)
   {
      stat = encode2(fs_resolution, user_info, encode_status_p);
      if (stat != (ERROR_CODE) no_errors)
         return(stat);
   }

   /* the encoding_tag is unknown */
   else
      return((ERROR_CODE) unknown_encoding_name);

   return((ERROR_CODE) no_errors);
}

/*============================================================*/
   /* SUM1CODE */
   else
   if (strcmp(encoding_tag, "SUM1CODE") == 0)
   {
      stat = encode3(fs_resolution, user_info, encode_status_p);
      if (stat != (ERROR_CODE) no_errors)
         return(stat);
   }

   /* ONE_THR1 */
   if (strcmp(encoding_tag, "ONE_THR1") == 0)
   {
      stat = encode4(fs_resolution, user_info, encode_status_p);
      if (stat != (ERROR_CODE) no_errors)
         return(stat);
   }

   /* the encoding_tag is unknown */
   else
      return((ERROR_CODE) unknown_encoding_name);

   return((ERROR_CODE) no_errors);
}

/*============================================================*/
/* Encoding scheme 1 */
```

```
ERROR_CODE encode1(fs_resolution, user_info, encode_status_p)
   short fs_resolution;
   char user_info[];
   ENCODE_STATUS *encode_status_p;
{
   short fv;          /* feature value */
   long  fv1;
   short fv_low;      /* minimum value of fv */
   short fv_high;     /* maximum value of fv */
   ERROR_CODE stat;   /* returned error code */
   char tag[16];      /* subspace tag */
   short patn1;       /* scaled pattern inputs*/
   short patn2;
   short patn3;
   short patn4;
   short patn5;
   short patn6;
   short patn7;
   short patn8;
   short patn9;
   short patn10;
   short patn11;

   extern pattern_t pattern;

   ERROR_CODE nls_feature_encode();
   ERROR_CODE nls_subspace_tag();


   /* Encode the first feature */
   fv1 = pattern.f1 * 10000;
   fv = fv1;
   fv_low = 0;
   fv_high = 10000;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* Encode the second feature */
   fv1 = pattern.f2 * 100;
   fv = fv1;
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* Encode the third feature */
   fv1 = pattern.f3 * 100;
   fv = fv1;
   fv_low = -30;
   fv_high = 150;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* Encode the fourth feature */
   fv1 =(100 * pattern.f4);
   fv = fv1;
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);
```

```
  /* Encode the fifth feature */
  fv1 = pattern.f5 * 1000;
  fv = fv1;
  fv_low = 0;
  fv_high = 1000;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);

  /* Encode the sixth feature */
  fv1 = pattern.f6 * 10000;
  fv = fv1;
  fv_low = 0;
  fv_high = 10000;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);

  /* Encode the seventh feature */
  fv1 = pattern.f7 * 100;
  fv = fv1;
  fv_low = 0;
  fv_high = 110;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);

/* Encode the eighth feature */
  fv1 = (1000 * pattern.f8);
  fv = fv1;
  fv_low = 0;
  fv_high = 3000;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);

/* Encode the ninth feature */
  fv1 = (10 * pattern.f9);
  fv = fv1;
  fv_low = 0;
  fv_high = 150;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);

  /* Encode the tenth feature */
  fv1 = (10 * pattern.f10);
  fv = fv1;
  fv_low = 0;
  fv_high = 100;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);

  /* Encode the eleventh feature */
  fv1 = pattern.f11 * 10000;
  fv = fv1;
  fv_low = 0;
  fv_high = 15000;
  stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
  if (stat != (ERROR_CODE) no_errors)
     return(stat);
```

```
   /* Set the subspace tag
   sprintf(tag, "%6hd", patn5);
   stat = nls_subspace_tag(tag, 12);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);*/

   /* This encoding scheme can not fail */
   *encode_status_p = (ENCODE_STATUS) succeeded;

   return((ERROR_CODE) no_errors);
}

/*==============================================================*/
/* Encoding scheme 2 */

ERROR_CODE encode2(fs_resolution, user_info, encode_status_p)
   short fs_resolution;
   char user_info[];
   ENCODE_STATUS *encode_status_p;
{
   float fv;           /* feature value */
   short fv_low;       /* manimum value of fv */
   short fv_high;      /* maximum value of fv */
   ERROR_CODE stat;    /* returned error code */
   extern pattern_t pattern;

   ERROR_CODE nls_feature_encode();

   /* Encode the new feature */
   fv = ( pattern.f1 + pattern.f2 +
         pattern.f3 +  pattern.f5 +
         pattern.f7 +  pattern.f8 +
         pattern.f9 + pattern.f10);
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* This encoding scheme can not fail */
   *encode_status_p = (ENCODE_STATUS) succeeded;

   return((ERROR_CODE) no_errors);
}
/*==============================================================*/

/* Encoding scheme 3 */

ERROR_CODE encode3(fs_resolution, user_info, encode_status_p)
   short fs_resolution;
   char user_info[];
   ENCODE_STATUS *encode_status_p;
{
   short fv;           /* feature value */
   long fv1;
   short fv_low;       /* manimum value of fv */
   short fv_high;      /* maximum value of fv */
   ERROR_CODE stat;    /* returned error code */

   extern pattern_t pattern;

   ERROR_CODE nls_feature_encode();
```

```
   /* Encode the new feature */
   fv1 = ( pattern.f2 + pattern.f6);
   fv = fv1;
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* Encode the new feature */
   fv1 = ( pattern.f1 + pattern.f7);
   fv = fv1;
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* Encode the new feature */
   fv1 =  pattern.f5;
   fv = fv1;
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* Encode the new feature */
   fv1 = ( pattern.f8 + pattern.f9 + pattern.f10);
   fv = fv1;
   fv_low = 0;
   fv_high = 100;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

   /* This encoding scheme can not fail */
   *encode_status_p = (ENCODE_STATUS) succeeded;

   return((ERROR_CODE) no_errors);
}
/*=============================================================*/
/* Encoding scheme 4 */

ERROR_CODE encode4(fs_resolution, user_info, encode_status_p)
   short fs_resolution;
   char user_info[];
   ENCODE_STATUS *encode_status_p;
{
   short fv;           /* feature value */
   short fv2;
   long  fv1;
   short fv_low;       /* minimum value of fv */
   short fv_high;      /* maximum value of fv */
   ERROR_CODE stat;    /* returned error code */
   char tag[16];       /* subspace tag */
   short patn1;        /* scaled pattern inputs*/
   short patn2;
   short patn3;
   short patn4;
   short patn5;
   short patn6;
   short patn7;
```

```
   short patn8;
   short patn9;
   short patn10;
   short patn11;

   extern pattern_t pattern;

   ERROR_CODE nls_feature_encode();
   ERROR_CODE nls_subspace_tag();


   /* Encode the first feature */
   fv1 = pattern.f1 * 10000;
   fv = fv1;
   fv_low = 0;
   fv_high = 10000;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);


   /* Encode the fifth feature
   fv1 = pattern.f5 * 1000;
   fv = fv1;
   fv_low = 0;
   fv_high = 1000;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);*/


   /* Encode the seventh feature */
   fv1 = pattern.f7 * 100;
   fv = fv1;
   fv_low = 0;
   fv_high = 110;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);

 /* Encode the eighth feature */
   fv1 = (1000 * pattern.f8);
   fv = fv1;
   fv_low = 0;
   fv_high = 3000;
   stat = nls_feature_encode(fs_resolution, fv, fv_low, fv_high);
   if (stat != (ERROR_CODE) no_errors)
      return(stat);


   /* This encoding scheme can not fail */
   *encode_status_p = (ENCODE_STATUS) succeeded;

   return((ERROR_CODE) no_errors);
}
```

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