

Design A Perceptron Neural Network Block With Complementary Training Function For Industrial PLCs By Ladder Language

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Abstract: Programmable logic controllers are the main controllers in the today's industries; they are used for several applications in industrial control systems and there are lots of examples from the PLC applications in industries especially in big companies and plants such as refineries, power plants, petrochemical companies, steel companies, and food companies. In PLCs there are some functions in the function library in the programming and configuration software that can be used in PLC programs as basic program elements. The aim of this project are introducing and implementing a new function block of a neural network to the function library of PLC. This block can be applied for some control applications or nonlinear functions calculations if it had been trained for desired applications. The implemented neural network is a Perceptron neural network with three layers, three input nodes and one output node. The block can be used in manual or automatic mode.

In this paper the structure of the implemented function block, the parameters and the training method of the network are presented. All of these are showed by considering especial subjects in PLC programming and its complexities. Finally the application of the new block is compared with a classic simulated block and the results are presented.

Keywords: Programmable Logic Controller, PLC Programming, Neural Networks, Perception Network, Intelligent Control

1. Introduction

Developing the new control strategies and implementation and extending new calculation tools in PLC systems are interesting subjects for PLC manufacturers

and special advanced users. Manufacturers presented new functions by introducing their new PLCs. They try to improve their last functions, simple to understand or applying by PLC users [6], [7]. So declaration of the new function blocks is an applicable research field in industrial control, however industrial applications of the neural network are limited by needs of the high level engineering knowledge in control, intelligence or level of automation and the applications. Moreover it needs to increase the reliability of neural network function block especially for industrial applications.

In PLCs, there are several mathematical and operational function blocks which can be used easily but neural network function block has not be defined in PLC which we know them [1],[6],[7]. Our study on most known PLC manufacturer products like siemens, Omron, Allen Bradley ,Yokogawa , Hitachi and ... show that NN is not implemented with PLCs yet. In this paper in the first section the importance of the subject and prior art are discussed.

Then in part II artificial neural networks are reviewed and then in Part III PLCs and PLC programming are studied and in part IV and V structure of the implemented neural network for PLC application and it's operation are introduced then in part VI the function block operation is analyzed in comparison with a simulated system and finally some conclusion have been made and the results are presented.

2. NEURAL NETWORKS

In a neuron, inputs information and parameters excite the input channel of a real neuron with an electric signal. Then these input signals are manipulated by the synapse (Weight) and the effect of them with impact of the other parameter (Bias) is used to excite the output of the neuron. In artificial NN synapses weight the input signals and they are added with a bias value finally decision function produce the output of the artificial NN. So neurons it produces a constant current in the output paths of the neuron toward other neurons that have link of them [3], [6].

An Artificial NN is a network of neurons model. NN has some distinct mathematical and graphical models. These models are used to show the structure of suggested artificial neural network.

To use a NN the parameters of the NN should be trained at first and then it can be used. There are two main topologies in neural networks. The first one is feed forward and the second one is feedback topology. Most of the recent applications of neural network use the feed forward topology. The most conventional method for feed forward NN training is the back error propagation method [4], [5].

Perceptron is one of the feed forward neural networks. Figure-1 Multilayer Perceptron networks are a example of feed forward neural network which have several applications in complex mathematical problem solving, classification and nonlinear equation solving. Multi layer Perceptron neural network can be used by proper selection of the network parameters and decision functions [3], [2] for a lot of problems.

In these networks there are an input layer as an input part of the network, an output layer as the output part of the network and some hidden layers which are used between input and output layers (Figure-1). In these networks the information passes straightforward the network to produce the output. There are considerable contributions on the use of perceptron neural networks for industrial control or calculation problems. [3], [4]

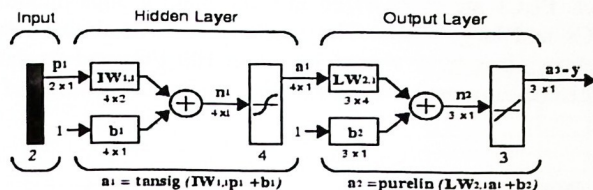


Fig-1 Multi layer Perceptron neural network

Table-1 Training routine of the Perceptron neural networks

$E(w) = \frac{1}{2} \sum_{j=1}^p (y_j - d_j)^2$	Y_j : network j-th output value, d_j : target value of j-th output, p see [1]: number of neurons in the output layer	1
$\Delta w_{ij} = -\eta \cdot \frac{\partial E}{\partial w_{ij}}$ $\Delta w_{ij} = -\eta \cdot \frac{\partial E}{\partial w_{ij}} \cdot \frac{\partial y_j}{\partial S_j} \cdot \frac{\partial S_j}{\partial w_{ij}}$ $\frac{\partial S_j}{\partial w_{ij}} = x_i$	These are the weight changes due to the j-th output y_j - j-th neuron output value, S_j - weighted total of output signals determined by the formula (1). See[1]	2
$\frac{\partial S_j}{\partial w_{ij}} = x_i$	x_i is the neuron i-th input value See[1]	3
$\frac{\partial E}{\partial y_j} = \sum_k \frac{\partial E}{\partial y_k} \cdot \frac{\partial y_k}{\partial S_k} \cdot \frac{\partial S_k}{\partial y_j} = \sum_k \frac{\partial E}{\partial y_k} \cdot \frac{\partial y_k}{\partial S_k} \cdot w_{jk}^{(n+1)}$	K is the number of neurons in layer $n+1$ See[1]	4
$\delta_j^{(n)} = \frac{\partial E}{\partial y_j} \cdot \frac{\partial y_j}{\partial S_j}$	$\delta_j^{(n)}$ n-th layer if we know $\delta_k^{(n+1)}$ of the next $(n+1)$ layer. See[1]	5
$\delta_j^{(n)} = \left[\sum_k \delta_k^{(n+1)} \cdot w_{jk}^{(n+1)} \right] \cdot \frac{\partial y_j}{\partial S_j}$	$\delta_j^{(n)}$ for the last layer of the neuron See[1]	6
$\delta_j^{(N)} = (y_j^{(N)} - d_j) \cdot \frac{\partial y_j}{\partial S_j}$	Network the vector of those values that the neural network must generate with the given set of input values. See [1]	7
$\Delta w_{ij}^{(n)} = -\eta \cdot \delta_j^{(n)} \cdot x_i^n$	And finally let's write down the formula (6) in expand form Weight function changes	8

3. Programmable logic controllers

PLCs are the most applied controllers in industrial application especially for interlocking and supervising control to make sequences of operation or safety logics. However the today's PLCs have control abilities for applying in continuous systems (like PID facility). It should be noticed that there are more than 100 manufacturers in the PLC forum. They produce various types of PLCs in different sizes. PLCs are categorized in three main groups including small PLCs, medium PLCs and large PLCs. The small sizes have almost less than 40 inputs/outputs, medium sizes have almost less than 100 I/Os and the large sizes have more than 500 I/Os. Figures 2 and 3 show the application strategy of a large PLC.

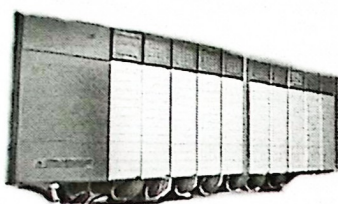


Fig-2 a large PLC

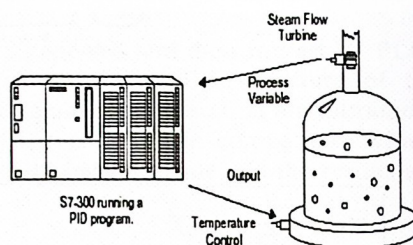


Fig-3 PLC application terminology

It should be noted that for comparing PLCs there are several other items. Some characteristics such as CPU, Cycle time, simplicity, reliability, expansion capability, peripherals, networking features are some considerable items.

The PLC systems can be programmed with three languages. These are Ladder programming (LAD), function block diagram programming (FBD) and statement list programming (STL). These methods of programming vary in different PLCs but they have a little difference between most of the PLCs. To write a structural PLC program, we have to use some basic instructions or some programmed blocks. It also needs to write some new blocks which should be programmed for the application.

The organization blocks (OB), program blocks (PB) and some function blocks (FB,FC) are some of these blocks in Siemens PLCs. For example OB blocks are function blocks manage the PLCs and they act like an operating system of a computer. They control PLC operation sequences and hardware parts of the PLC.

The PB blocks are program blocks; they can be used as the basic applied control program or the subroutine of the user programs. The FC blocks are basic applied functions in the PLC systems. They perform a simple software or hardware task which generally can be used by the user program. Some of these blocks have been designed or reserved by PLC manufacturers and some others can be programmed by the user of the PLC due to the applications. Usually FC blocks are used in PB Blocks; PB and FC blocks are used in OB blocks. It should be noted that the main

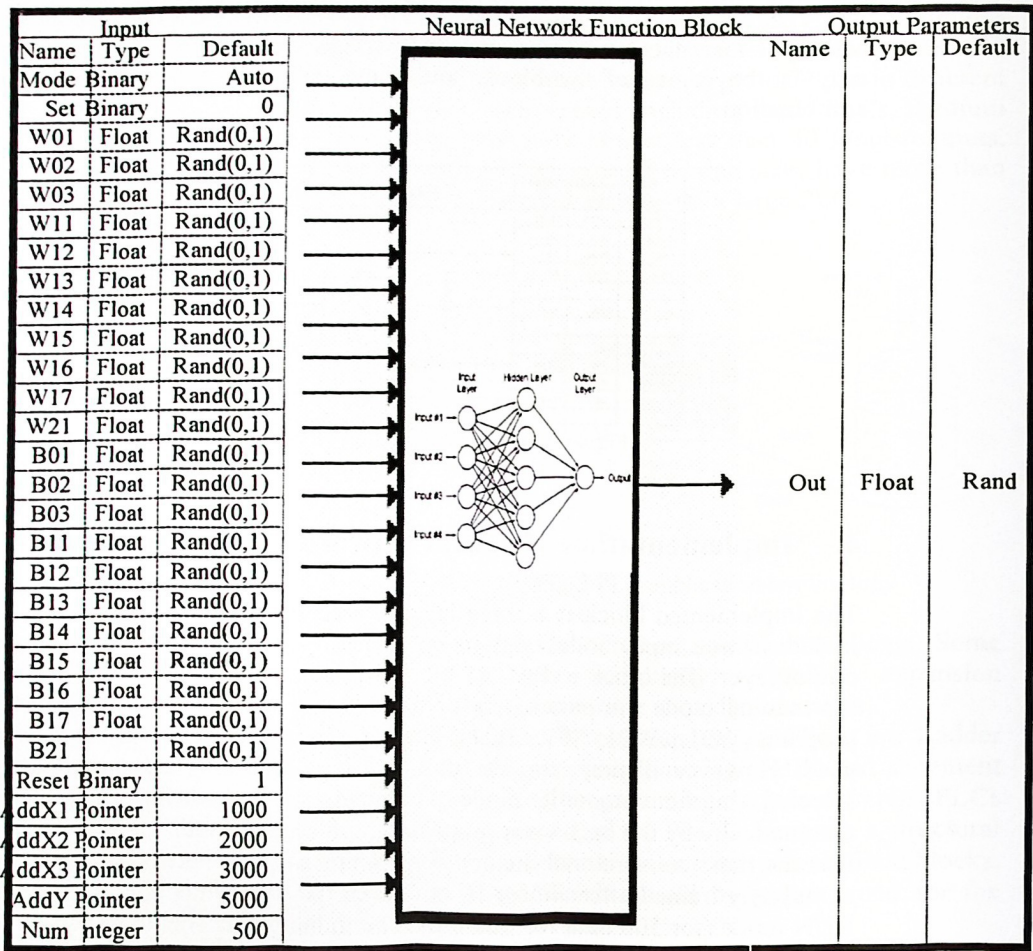


Fig-5 Implemented function block

5. Operation

To test the designed network in a siemens PLC, the behavior of a PID controller for a first order simple model is studied in Matlab software. The model is used to extract data to form four vectors, the samples are gathered from almost 8 minutes analyzing of the PID controller on the model with 1000 sampling points. Table 2 shows the sampled data variables and related their considerations. The information of the PID controlled systems transferred to the desired places in PLC memory to make the training matrix for the neural network. Then the block is trained by the matrix. After that the behavior of the network is compared with the PID controlled in the model to analyze the operation of the implemented neural network function block. Figure 6 compares the Function block in PLC with the PID controller due to applying a five level set point both in model and PLC. Some other inputs are used in manual mode for manual parameter defining of the NN. Others are for control the operation and stages.

Table 2- Training matrix variables

Type	Name	Address	NN Name
Input	Set Point	MW1000-1999	X0
	Error	MW2000-2999	X1
	Control Output	MW3000-3999	X2
Output	Process Variable	MW5000-5999	Y

6. Conclusion

In this paper the structure of neural networks by aiming of the implementation in the industrial PLCs are studied. The new function block is introduced for the PLCs applications and the operation of the block is studied too. Then the accuracy of the implemented block is investigated regarding to the calculation and programming limits of the PLCs. In addition the back error propagation training method is implemented by PLC software as a complementary PB. Then the implemented function is analyzed by using a computer controlled model. The presented results show that the function performs the desired operation. It should be noted that this application is gathered based on the fully industrial controller

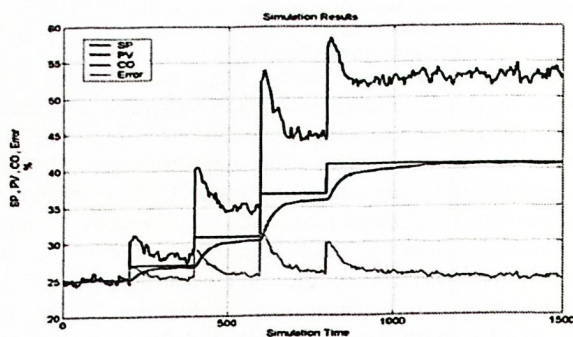


Fig 6 – Neural network block output compare to PID output

7. Acknowledgments

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