wjert, 2019, Vol. 5, Issue 1, 128-138. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.218

APPLICATION OF ARTIFICIAL NEURAL NETWORK IN OPTIMIZATION OF SOAP PRODUCTION

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Article Received on 07/11/2018 Article Revised on 28/11/2018 Article Accepted on 19/12/2018

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ABSTRACT

This project was aimed at optimizing soap production profit using Neural Network programming. In this project a Neural Network was trained using a data set of solved linear programming problems. The objective function used in this training had two (2) variables and three (3) constraints equations. This trained Neural Network was used to optimize soap production profit for two different kinds of soap; bathing and laundry soaps. The Neural Network structure consisted of eleven (11) inputs and 3 outputs with a neural structure of 2 hidden layers and 50 neurons. The training algorithm used was feed-forward back propagation with a Bayesian Regularization error. The Neural Network results when compared with traditional simplex method of optimization, proved to be 98% accurate. The maximum projected profit was up to a 91% increase from ₦30,625 to ₦58,500 in a month. This research will increase the current rate of soap production in Patrich Global Enterprise and increase the profit of production while maintaining the same quantity of raw materials for monthly soap production.

KEY-WORDS: Artificial Neural Network, Back Propagation, Linear Programming, Hidden layer, Multi-layer feed-forward.

I. INTRODUCTION

In modern day solving of mathematical problems, Neural Network (NN) algorithms are applied in obtaining the shortest possible way to the most feasible solution. These algorithms in the Neural Network solve complex problems through the network of neurons. This project tends to offer a model of optimization through the application of neural network in linear programming. This project would show how a feed-forward neural network can be trained using back propagation to optimize production. In this project, a soap production Company was used as case study.

According to Kourosh et al (2013) Linear programming includes the optimization of a linear objective function that has a series of limitations in form of linear equality and inequalities. The aim of linear programming is to use a mathematical model to get the best output (e.g. maximum profit, minimum cost). Linear programming is mainly used in commercial and economic situation; however, it can be used for some engineering problems. Some of the industries that used linear programming are transportation, energy, telecommunications and factories. In addition, it is useful in modeling issues of planning, routing, scheduling, allocation and design. An evaluation of 500 largest companies in the world showed that 85% of them have used linear programming (Kourosh et al, 2013).

The neural network can best be likened to the connections and links of neurons in the biological nervous system and the brain in a living organism. The Neural networks according to Fogel et al (2016) are potentially and massively parallel-distributed structures that possess the ability to learn and generalize. According to the Authors, the neuron is basically the information processing unit of a neural network and the basis for designing numerous neural networks.

II. LITERATURE REVIEW

2.1 Back Propagation Algorithm

Mirza (2010) did a thesis on back propagation algorithm and the Author observed that it was one of the most used Neural Network algorithms. A research also done by Raul (2005) claimed that BP algorithm could be broken down to four main steps. From this book (Raul 2005), it was observed that after the weights of the network are chosen at random, the back propagation algorithm is used to compute the necessary corrections. The back propagation algorithm can be explained in the following:

The first stage is the feed forward computation. The feed-forward computation is done through back propagation to the output layer and then from the output layer, the neural network then moves the computation into the hidden layer where it is processed and then the weights are updated to suite the input to give the required output.

This process continues until error function becomes insignificant and then the algorithm is stopped. During the last step, the weight update usually happens throughout the algorithm of the network.

This back propagation method is suitable for teaching the neural network since the Network is required to study the relationship between the input and the output and then later tested with inputs to produce similar kind of outputs.

III. RESEARCH METHODS

3.1 Linear Programming Model

Linear programming optimization technique according to Lily (2015), is used widely by managers to try to make the best use of available resources. This can be applicable under these conditions:

i. Limited available resource.

ii. When the available resource has to be allocated to other competing activities

iii. A linear relationship exists between the variables in the problem.

For the case study to be used in this work, all the above listed conditions are satisfied. A model by Sharma (2005) on linear programming will be applied in solving this problem.
Let the objective function to be maximized be 'Z'.

Optimize (max or min) Z = $C_1x_1 + C_2x_2 + \ldots + C_nx_n + 0s_1 + 0s_1 + \ldots + 0s_m$

Subject to:

$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n + s_1 = b_1$

$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n + s_2 = b_2$

$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n + s_m = b_m$

Where: $x_1, x_2, \ldots x_n, s_1, s_2 \ldots, s_m \geq 0$

The objective function to be used becomes;

Optimize (Max or Min) Z = $\sum_{j=1}^{n} C_j x_j + \sum_{i=1}^{m}(0s_i)$ (3.1)

Subject to; $\sum_{j=1}^{n} a_{ij}x_j + s_i = b_i$ (3.2)

In matrix form;

Optimize (Max or min) Z = CX^T (3.3)

Subject to;

Ax + s = b, where x and s ≥0. (3.4)

From the above equations, in relation to production parameters;

Z = overall production profit to be optimized;

X= the amount of products to be optimized;

b =constraints of production;

A = Materials required for production;

s = slack variable;

The objective function for the Company will be modeled using this linear programming equation.

3.2 Neural Network Model

The artificial neuron functions like a brain. Abdulkareem and Fath (2014) observed that the ANN consists of several neurons interconnecting to create a network of neurons. The artificial neural network consists of three (3) layers:

i. Input Layer: which is responsible for receiving information.

ii. Hidden Layer: Which processes the information

iii. Output layer: Gives results from the processed information as seen in figure 1.

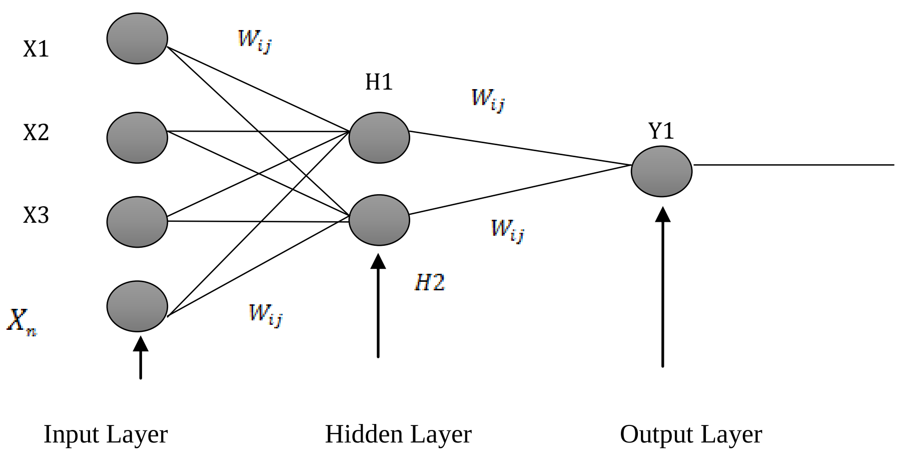

Figure 1: Structure of a Multilayer Feed-Forward Neural Network.

Where;

Y_i = Output variable

X_{ij}= Input variable

W_{ij} = Weights between layers

H_{ij}= Hidden layer containing activation/ Transfer function

Mathematically,

F(x) =Y_i= $\sum_{i=1}^{n}((X_{ij})(W_{ij}) - (H_{ij}))$

The neural network can be used for linear programming optimization problems by using the structure above to relate with the LP equation; A back propagation algorithm will be used to teach the neural network on solving the optimization problems.

3.3 Training of Artificial Neural Network

In setting up the neural network for training, the data had to be arranged in the form of input variables and output variables. For this case of linear programming as seen in figure 3.1, eleven (11) input variables and three (3) output variables were used to train the network. The number of neurons used for the training of the network was set at 50 neurons, this enables the weight (W) and bias (b) of each neuron to be adjusted to suit the size of the network.

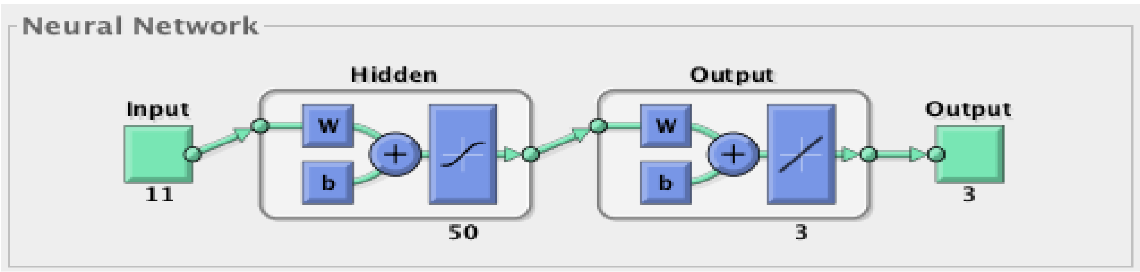

Figure 2: Structure of the Network with the Input and Target Variables (MATLAB).

Table 1: Training, Testing and Validation Data Set (sample).

S/n	a11	a12	b1	a21	a22	b2	a31	a32	b3	c1	c2	X1	X2	Z
1	2	3	10	1	2	9	4	6	15	4	5	3.75	0	15
2	3	1	6	3	3	8	5	2	12	3	4	0	2.667	10
3	1	2	7	2	1	12	1	3	8	4	5	5.667	0.667	26
4	4	3	12	1	2	23	2.55	7	17	6	2	3	0	18
5	5	5	15	3	3	32	7	7	28	5	4	3	0	15
6	2	1	6	1	2	12	4	5	25	6	3	3	0	18
7	1	3	8	3	1	14	1	5	10	8	5	4.2857	1.1429	40
8	4	2	9	3	2	11	7	3	20	9	18	0	4.5	81
9	6	4	20	2	3	16	2	2	9	11	22	0	4.5	99

A data set of about 140 linear programming problems were used in training the neural network to be able to adjust and predict solutions in the format of a linear programming problem with two (2) variables and three (3) constraints equations. In table 1, the sample of training, testing and validation data can be seen. Also appendix G contains complete training, testing and validation data set.

3.4 Data Collection Source

The data for this project work was collected from Patrich Global Enterprise. Patrich Global Enterprise (PGE) is a soap manufacturing Company located in Rivers State, Nigeria. The Company specializes in the production of cosmetics and different kinds of soap. For the purpose of this project, the soap production will be the area of concentration.

The data collected are based the following categories of raw materials required for the production of soap which are:

i. Oils (kernel oil, palm oil),

ii. Sodium compounds (Sodium Hydroxide, Sodium Carbonate & Sodium Sulphate) and

iii. Additives (fragrance, menthol and color).

These materials are passed through the following processes; Chemical Preparation, Drying and Packaging. The production data for January 2018 to June 2018 As seen below.

For the input data

Let the number of laundry soap to be produced each month = x_1 and bathing soap to be produced each month = x_2,

Max Z = $x_1 c_1 + x_2 c_2$ (3.10)

Subject to;

$a_{11}x_1 + a_{12}x_{2<=} b_1$ (3.11)

$a_{21}x_1 + a_{22}x_{2<=} b_2$ (3.12)

$a_{31}x_1 + a_{32}x_{2<=} b_3$ (3.13)

After substituting the various values into the equations above, we get the following for the month of January

Optimize (Max) $Z = 65x_1 + 75x_2$ (3.14)

Subject to:

$10x_1 + 8x_2 <= 7500$ (3.15)

$17x_1 + 12x_2 <= 12000$ (3.16)

$0.5x_1 + 0.7x_2 <= 400$ (3.17)

For the Month of February

Optimize (Max) $Z = 70x_1 + 80x_2$ (3.18)

Subject to:

$15x_1 + 12x_2 <= 10000$ (3.19)

$20x_1 + 15x_2 <= 15000$ (3.20)

$0.9x_1 + x_2 <= 500$ (3.21)

For the Month of March

Optimize (Max) $Z = 75x_1 + 95x_2$ (3.22)

Subject to:

$30x_1 + 14x_2 <= 15000$ (3.23)

$15x_1 + 10x_2 <= 11000$ (3.24)

$0.45x_1 + 0.85x_2 <= 450$ (3.25)

For the Month of April

Optimize (Max) $Z = 75x_1 + 95x_2$ (3.26)

Subject to:

$22x_1 + 15x_2 <= 12000$ (3.27)

$27x_1 + 18x_2 <= 25000$ (3.28)

$0.57x_1 + 0.92x_2 <= 359$ (3.29)

For the Month of May

Optimize (Max) $Z = 80x_1 + 100x_2$ (3.30)

Subject to:

$20x_1 + 18x_2 <= 12400$ (3.31)

$16x_1 + 20x_2 <= 18000$ (3.32)

$0.5x_1 + 0.6x_2 <= 435$ (3.33)

For the Month of June

Optimize (Max) $Z = 85x_1 + 110x_2$ (3.34)

Subject to:

$19x_1 + 14x_2 <= 10000$ (3.35)

$25x_1 + 25x_2 <= 20000$ (3.36)

$0.7x_1 + 1.2x_2 <= 500$ (3.37)

The above equations are converted into linear programming model as shown in a table format on Table 8. This enables the Artificial Neural Network to understand the various inputs in a tabular form in the same manner of the training data sample.

Table 8: Data for Soap Production for the Months of January to June in Linear Programming Form.

S/n	a_{11}	a_{12}	b_1	a_{21}	a_{22}	b_2	a_{31}	a_{32}	b_3	c_1	c_2
1	10	8	7500	17	12	12000	0.5	0.7	400	65	75
2	15	12	10000	20	15	15000	0.9	1	500	70	80
3	30	14	15000	15	10	11000	0.45	0.85	450	75	95
4	22	15	12000	27	18	25000	0.57	0.92	359	75	95
5	20	18	12400	16	20	18000	0.5	0.6	435	80	100
6	19	14	10000	25	25	20000	0.7	1.2	500	85	110

IV. RESULTS AND DISCUSSION

4.1. Neural Network Optimization Results for Maximum Profit

During the Maximum Profit Optimization, the convergence point started at around 300^{th} epoch and best performance occurred around the 656^{th} epoch (as seen on Figure 7) with the performance value at 0.92233. This was the convergence point where the best results for the optimization was gotten for the Bathing Soap production.

The errors from the Maximum Profit Optimization (as seen on figure 8) can be also had 20 bars (bins) of errors. It also was observed that the errors were high during the training process but then reduced significantly during testing.

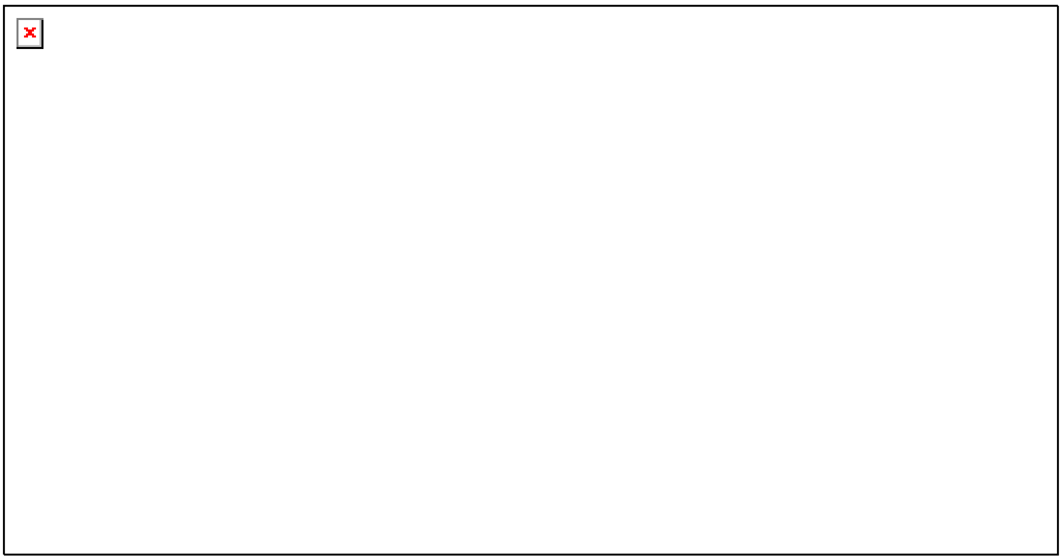

Fig 7: Maximum Profit Optimization Performance.

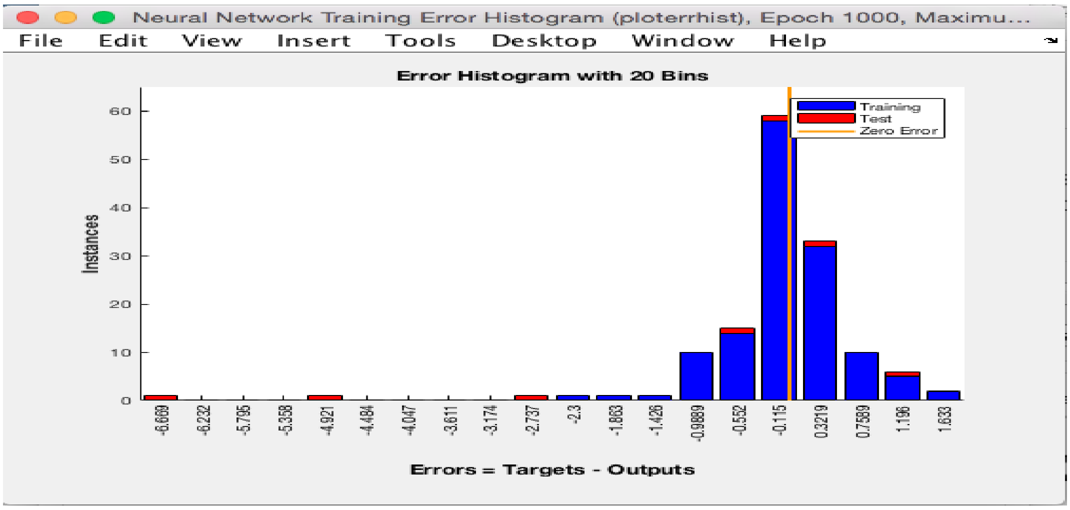

Fig 8: Maximum Profit Optimization Errors.

4.4. Comparing Results of Artificial Neural Network Solution with Simplex Method

The neural Network was able to optimize soap production and the maximum profit for each month can be seen on table 7. From the optimized results gotten, the corresponding values were compared with by solving the same problems using the simplex method.

The simplex method was also used to optimize the system. The Company's production data for the months of January 2018 to June 2018 can be found on table 7.

Table 7: Company Profit, Results from Simplex Method and Optimization Results from Artificial Neural Network for the Months of January to June 2018.

Month	Company Profit(₦)	Maximum Profit (₦) (Simplex Method)	Maximum Profit (₦) (Neural Network Method)
January	30,000	49800	49830.9972
February	28700	40000	39998.0210
March	30625	58500	58544.0084
April	47000	56800	56832.0183
May	46800	68888.89	68888.9075
June	47200	53846.15	53840.1682

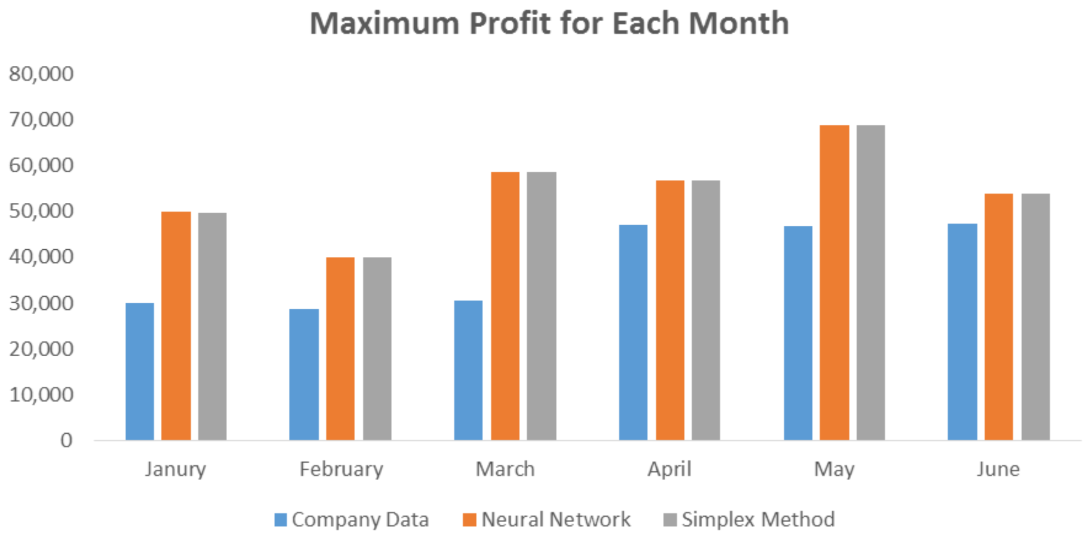

Figure 9: Comparison of Results from Company Data, Neural Network and Simplex Method for Maximum Profit from Production of Both Laundry and Bathing Soap.

For each month during optimization, it was observed that the maximum profit was more than the Company's recorded profit. This shows that the profit being generated from the Company for these months was not the maximum attainable profit from production as seen on Figure 9.

It was observed that maximum profit prior to this optimization process was at ₦47,200 at the same cost per unit of each soap. After optimization was done, the maximum projected profit was approximately ₦69,000 which is about a 47% increase in maximum profit from current production data.

V. CONCLUSION

From this project, Artificial Neural Network was modelled and used to optimize soap Production for Patrich Global Enterprise. A back propagation algorithm where the network is able to learn from its set targets was used for this optimization. The network was able to achieve up to 1000 iterations where the error values between the targets and output became lowest.

After Optimization with the Artificial Neural Network, solutions from simplex method of solving linear programming problems was used to compare with the results from the Artificial Neural Network to confirm and ascertain the optimized results. After the comparison of results, it was observed that the both (Neural Network and Simplex) results were over 98% percent in similarities.

The maximum projected profit was also effected with a 47% increase in profit from ₦47,200 to ₦69,000 in a month. However, production of bathing soaps will be more profitable in production than laundry soaps. More resources should be put into the production of bathing soaps for higher profit margins.

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