WHITE PAPER: BENEFITS OF USING NEURAL NETWORKS IN PRICE & PROMOTIONAL DEMAND FORECASTER™

by Michael J. Cavaretta, PhD

1. Neural Networks Generalize on Examples

Neural networks generalize on training data. This allows the **PRICE & PROMOTIONAL DEMAND FORECASTER™** neural network based forecasting model to make forecasts even when specific causal factor values are not represented in the training data. For example, consider a set of training data containing five distinct price discounts; 0%, 5%, 10%, 15%, and 20% each with an increasing associated lift. A neural network is trained using this data. If this neural network is used to forecast in a situation where the price discount is 17%, the forecasted lift would be between the 15% discount and the 20% discounts in the training data. Basically, the ability of neural networks to generalize allows them to represent overall demand patterns rather than specific demand instances.

2. A Neural Network Does Not Require all Factor Inputs

Neural networks work in parallel. Therefore, even when a causal factor, i.e. promo display, is used infrequently (or not at all) by a customer, the **PRICE & PROMOTIONAL DEMAND FORECASTER™** neural network is able to make a forecast using the other causal factors, i.e. promo pricing, advertising. This ensures the accuracy of the forecast doesn't degrade when only some of the causal factors are used.

3. Neural Networks Can Handle Non-linear Relationships

Promotional sales forecasting is a complex problem involving non-linear relationships. There are two types of non-linear relationships, those within individual factors and those between factors.

- Non-linear relationships within individual factors indicate that the effect of a causal factor on lift changes as the value of the causal factor itself changes. For example, consider the effect of price discount on lift. Let's say there is a price discount of 10% on a particular item causing a lift of 100%. Increasing the price discount to 20% provides a lift of 150%. Thus, doubling the price discount (i.e., from 10% to 20%) does not double the lift (150% versus 100%).
- Non-linear relationships between factors indicate that the effect on lift of changing a causal factor is dependent upon the value of other causal factors. For example, increasing the external promotion when price discount is high will likely produce a smaller change in lift than when the price discount is low.

4. It is Easier to Describe Relationships than Code Them

Churchill's experience indicates it is much easier to illustrate relationships using examples of promotions, their causal factors and associated lift than to specifically describe all the possible relationships between the factors. The data used to train the **PRICE & PROMOTIONAL DEMAND FORECASTER™** neural network is based on industry data. This database allows the neural network to encapsulate Churchill's expertise regarding the generalized effect of promotional factors on lift. The use of sensitivities in the model enables customization for specific promotional environments.

5. Why Pre-train Neural Networks

- **Pre-training hides complexity of neural networks:** Neural networks represent factor relationships using weights. The weights are generated during the training process. Training a neural network takes each record of the training database and forecasts lift. The weights are adjusted according to the error of the forecast (this is called the back-propagation training method). Forecasting is accomplished by multiplying the factor values by the weights, then summing them and using a sigmoid transfer function to scale the output. The amount of adjustment to the weights and when to stop adjusting are just two of the many parameters required by the training process. This training process requires many cycles through the data that can take hours or days and require a number of experiments with different training parameters. Using a pre-trained neural network allows this complex training process to be hidden from the users of **PRICE & PROMOTIONAL DEMAND FORECASTER™**.
- **The training data can also account for some of the complexities of neural networks.** For example, the sigmoid transfer function squashes the values toward the upper and lower ranges. Thus, these areas are emphasized in the training database.

6. Neural Networks run very quickly:

As mentioned in the above section, forecasting using neural networks is accomplished by multiplying the weights by the factors, summing the result and using the sigmoid transfer function. Therefore, neural networks run very quickly for two reasons:

- They work on all of the factors in parallel (see above)
- Only basic mathematical operators are required to calculate the lift value.

The speed of neural networks is very important as the number of items that must be forecast could easily be in the thousands.

7. Lift over Base Demand:

The current **PRICE & PROMOTIONAL DEMAND FORECASTER™** utilizes the forecasting model to forecast a promotional lift over base demand. In customizing the pre-trained neural network, causal factors are tuned to effectively forecast the lift in demand associated with those causal factors.

8. Pre-trained NN can easily be replaced by custom-trained NN when appropriate.

The current **PRICE & PROMOTIONAL DEMAND FORECASTER™** pre-trained neural network can be manually tuned to increase forecasting accuracy. However, when a sufficient amount of data has been collected, a custom neural network can be trained using customer data. This new neural network model can then be added by simply plugging it into **PROMOTIONAL DEMAND FORECASTER™.**