A Blend of Neural Network and Genetic Algorithm in Predicting Consumer Response Behavior

Aaina Dhingra
University Business School, Guru Nanak Dev University, Amritsar, Punjab, India
*Corresponding Author: aainadhingra66@gmail.com

Rishi Raj Sharma
Department of Business Management, Guru Nanak Dev University, RC, Gurdaspur, Punjab, India
rrishisharma@yahoo.com

Rama Bhardwaj
DAV College Amritsar, Computer Science & IT, Amritsar, Punjab, India
rima_bhardwaj@yahoo.com

[Abstract] The present study aims in exploring the theoretical base of neural networks as further complimented by genetic algorithms. The proposed model exhibits how neural networks guided by genetic algorithms can be employed to analyze the aspects by which customers' intentions are affected through interaction with multiple variables used for determining overall retail shopping values. The study suggests a framework consisting of genetic algorithm with a proposed artificial neural network, which is implemented in three stages. The study concluded that neural networking complimented by genetic algorithms will track and achieve better model interpretability in the brains of persons to judge consumer response behavior in retail businesses.

[Keywords] consumer behavior, genetic algorithms, neural network, predictive accuracy, retail shopping value

Introduction

In the present state of affairs, the basic challenge for marketers is to forecast the purchase intentions of the customer. The marketers need to smartly make use of the historic data of the customers to predict the consumer behavior (Shen, 2017). Previously, access to customer data was easy and affordable because of its preciseness and brevity. However, nowadays, after the explosion of data, the amount of data is large and much noisier. Therefore, a key challenge for marketers is to handle, analyze, and interpret customer data effectively and use it in an appropriate manner.

The initiative should be in utilizing customers' data, such as their demographics, lifestyle data, previous purchase and credit records for better understanding of customer taste and preferences, thereby connecting with prospective customers (Maintz & Zaumseil, 2019). Earlier marketers used to determine consumer behavior and purchase intentions customarily by using demographic and psychographic lifestyle factors. However, with the advancement of neurophysiological science, marketers have been able to attain more objectivity in their predictions. Their focus has shifted from perceptual mapping based on the psychological preferences to brain mapping of the respondent.

The technological innovation leading to neural sciences and neural networking is recent, and the emerging field of artificial intelligence; it can embed evolutionary computing techniques, like genetic algorithms for finding optimal predictive solutions in the area of marketing and research. The genetic algorithms contemplated with neural networking may provide predictive accuracy and optimization, which deals with the dilemma of natural selection of products in the market place and, consequentially, and may result in "the best" survived product.

In the current, technologically dynamic environment, the need for marketers is to reach into buyer's mind rather than just relying on his perceived behavior. The present study aims to discuss a unified genetic

algorithm and neural networking approach. In the study, the genetic algorithm will help the neural network model to find the optimal solution for discovering consumer response behaviors to determine the retail shopping value.

Literature Review

Neural networks have gained popularity in the business arena and in the field of marketing (Lee et al., 2008). It is one of the most stirring developments of information technology in the business world (Lin & Bruwer, 1996). Neural networking is being used to solve many problems associated with market segmentation, forecasts and predictions associated with business, consumer buying behaviors, and target marketing (Curry & Moutinho, 1993).

Law and Au (1999) predicted the arrival of tourists in Hong Kong using a feed forward neural network. The forecasting result showed that the neural network technique outperformed other statistical techniques with better accuracy. Tsaur et al., (2002) investigated the determinants of guest loyalty to international tourist hotels using a neural network approach, wherein an ANN model showcased better results than regression. However, Moutinho et al., (2001) examined critical factors in consumer supermarket shopping behavior using the neural network approach to identify the major elements of customer satisfaction in the British grocery retail industry. Supplementing a previous study, Chiang et al., (2006) predicted and explained patronage behavior, consumer choice towards web and traditional stores using neural networks and compared it with logistic regression.

Chowdhury and Samuel (2014) used ANN to understand the behavior pattern of customers while purchasing energy-efficient products; Yaser (2018) combined use of EFA and ANN to explore a hybrid model of consumption of organic food. No doubt, the ANN technique provides predictive solutions for multivariate analysis, but there still is a pressing need to find the optimal solution. Hence, in this scenario, genetic algorithms play their role as a major counterpart. The synergetic effect of these two may generate a path for the managers to follow and rely on for the solution to effective decision making.

Genetic algorithms are general purpose search algorithms for solving complex problems and are used for optimization and classification (Kuo et al., 2001). These algorithms, steered by the biological evolution mechanism of reproduction, crossover, and mutation are used to effectively explore a complex space in an adaptive way. In addition, Ritchie et al., (2003) opined neural network inputs, weights, and interconnections are optimized using a genetic algorithm for a specific problem while decreasing the susceptibility to overfitting, which happens in traditional back propagation neural networks. The study revealed that genetic programming optimized neural network and has a low prediction error; hence, it outperforms the traditional neural network approach.

In addition, Kuo et al., (2001) used genetic algorithm for modifying a population of artificial structures through application of genetic operators. Similarly, Kim, and Han (2000) revealed that genetic algorithms not only improved the learning algorithm, but also reduced complexity in the feature space by reducing and eliminating the irrelevant factors. In addition, according to Pendharkar (2009), usage of a genetic algorithm with a neural network model maximized the predictive accuracy of the customer churn. However, Fish et al., (2004) used an artificial neural network trained with a genetic algorithm because of improved performance to model brand share and consumer choices in a retail coffee market. In addition, Chiroma et al., (2017) revealed that neural network and genetic algorithm optimization focused on optimization of weights, topology, and subset selection of features and training.

Neural Networks and Genetic Algorithm

When a neural network model is formed, it operates in a backward manner and ascertains the set of input variables and results in the anticipated value of the output. There is difficulty in finding the optimal set of inputs and outputs because of outsized number of variables and the non-linear nature of existing models (Kemp, 2006). Consequently, usage of genetic algorithms is executed because it has the ability to solve a problem by obtaining an accurate and precise optimal solution.

A genetic algorithm is a search algorithm used for improving the performance and predictive accuracy of artificial intelligence techniques (Kim & Han, 2000; Kuo et al., 2006). The fundamental approach of a

genetic algorithm is to have a collection of populations with potential and better solutions for specified input problems. It practices the principle of natural genes, genetics, and evolution to continually amend a population of artificial constructs with the use of various parameters, such as initialization, selection, crossover, and mutation, in order to obtain an optimum solution (Chiroma et al., 2017).

A hybrid of the neural network and genetic algorithm has been effectively applied to solve several problems with varying level of complexities in numerous areas of business (Chiroma et al., 2017). The genetic algorithm is an evolutionary algorithm popularly taken into consideration because it works well with neural networks and helps to choose the network topology, such as enhancing relevant features subset, devising the optimal number of hidden layers, the activation function, the connection weights, processing the elements, and search for the best model (Chiroma et al., 2017). In addition to this, numerous studies have been conducted related to a genetic algorithm where it has been applied to optimize neural network architecture (Fish et al., 2004; Ritchie et al., 2003). The rationale behind the hybrid intelligence of a neural network and a genetic algorithm is that it delivers improved usage of multiple input variables by contributing a reduced set, thereby reducing the computational time and increasing the efficiency (Inthachot et al., 2016).

Hence, a genetic algorithm eliminates the irrelevant pattern in neural network (Kim & Han, 2000). Fish et al., (2004) suggested the usage of a genetic algorithm with an artificial neural network in two areas, namely optimizing connection weights and optimizing the network architecture. Initially, different search methods were practiced by researchers to identify the connection weights, but later to optimize the weights; they opted for genetic adaptive neural network training (Ritchie et al., 2003). In the present study, the aim is to make use of a genetic algorithm aimed at optimization of a neural network model and, thereby, receive the best fit solution among the inputs and outputs of the neural network.

Neural Networks Guided by Genetic Algorithms for Consumer Response Behaviour

The researchers are predicting the shopping behaviour of consumers with a hybrid of neural networks and genetic algorithms (Fish et al., 2004; Toth et al., 2017) and, consequently, identifying the purchase intentions and consumer response behavior of the customer (Erkan & Elwalda, 2018; Sheil et al., 2018).

In the study, a hybrid framework of a genetic algorithm and a neural network is proposed and illustrated in Figure I. The figure indicates the usage of the genetic algorithm for the proposed consumer response behavior model, which is further portrayed through a neural network. The framework depicts that an artificial neural network and a genetic algorithm both work together in coordination with each other. The artificial neural network takes up information from external sources, and the network is, also, given training to perform the function it intends to. The information from the artificial neural network is sent to the genetic algorithm for further processing.

The genetic algorithm examines and finds optimal solution for a set of feature subsets and passes them to the artificial neural network. An artificial neural network receives the feature subset, which is a reduced set of variables, processes the results and generates the output, which is then, again, sent to the genetic algorithm. The genetic algorithm receives the varied options of the outputs, evaluates them, and, in advance, reduces the results to obtain the best optimal solution. For each output set, we repeat the procedure until the test set is checked once, and we attain the optimal solution among the proposed options of the outputs. The best subset of output is received from the hybrid operation of an artificial neural network and a genetic algorithm, which is the final, optimal solution, estimated accurately, and does prospect prediction.

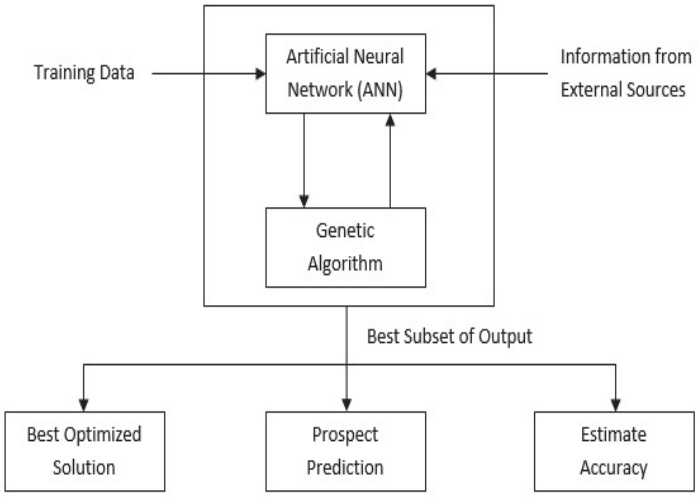

Figure 1. Proposed Framework of Artificial Neural Network and Genetic Algorithm Model

The above-mentioned concept of machine learning encapsulated with genetic algorithms will, therefore, lead towards knowing the exact determinants of the buying behavior of consumers in a more scientific way and will accomplish the predictive accuracy of a neural model. In a nutshell, we can say that neural networking complimented by genetic algorithms will track and achieve better model interpretability existing in the brains of consumers.

Proposed Model of Neural Network Guided by Genetic Algorithm to Understand Consumer Response Behavior

The present study proposes a neural network to evaluate the purchase intention of customers based upon overall retail shopping value. A conceptual model is proposed in Figure 2 that puts forth the retail shopping value, which is attained through five latent variables. These variables correspond to perceived merchandise quality, perceived service quality, perceived product price, pleasure, and arousal. Subsequently, the retail shopping value that has been attained would result in predictive analysis aimed at judging the varied intentions of the customer. The varied intentions that are taken up in the study deal with the intention to explore, intention to purchase, intention to revisit, and intention to recommend. These intentions are consistent with the satisfaction, loyalty, and retention of the customer in the retail market, and it is one of the causal results of behavioral responses showcased by a consumer (Meydanoğlu et al., 2018; Overall, 2017).

Perceived Merchandise Quality

The merchandise quality is one of the basic initiators that influences the customer and builds an intention to purchase. It is the usability, virtual product experience, and perceived usefulness of the merchandise that acts as a quality dimension for customer satisfaction resulting in purchase intention (Erkan & Elwalda, 2018). The customer's willingness to buy a product is associated with the perceived product quality, the relative price in accordance with the quality, the value attainable by the product, and the willingness of the customer to buy (Beneke et al., 2013).

Perceived Service Quality

Consumers' perception of service quality validates the positive or negative effect of the service on customer satisfaction and thereby acts as a significant determinant for customers to make a purchase. According to

the customer, if the service quality provided by the online and offline retailer is worthy and remarkable, then the merchandise offered to the customer would be even superior (Janda et al., 2002). Kim and Jin (2002) proposed, designed, and validated retail service quality scales for customers to examine their perceived service quality of online shopping sites and discount stores.

Perceived Product Price

The customers' buying and purchase intent for a particular product is influenced by the price of the product and the value it offers in accordance with its price (Dodds, 1991). Perceived gain or loss associated with the price of the product mainly controls the purchase intent, and the customer might alter his or her decision of the purchase based on the price fluctuations in the market place and space (Pelegrín-Borondo et al., 2015). Matzler et al. (2006) explored dimensions of satisfaction associated with the price in the retail industry and also devised the influence of the environment prevailing in the retail space on the pricing perception of the customers.

Pleasure

Pleasure is an emotion that is responsible for and supportive of the feeling of enjoyment in the minds of the customer. It creates an optimistic impact on the thoughts of customers, thereby encouraging them to make a purchase. Cox et al., (2005) examined the effects of induced arousal and the pleasure of shopping across the various channels of shopping, such as the internet and physical stores.

Arousal

Customers show different types of emotions while buying and shopping in a retail store. Arousal is one of the emotional states that stimulates a customer to exhibit a response to stimuli in a retail environment. The emotions of a customer induced by atmospheric stimuli can be measured through his or her attitude, established through the moods, feelings, and judgements of his or her own. The judgments are there because of responsible categorisation of stimuli, such as being pleasant, amiable, being attractive, or being opposite of all of these (Hwang et al., 2012). Wirtz et al. (2007) opined that customer satisfaction is associated with the state of arousal and severely impacts the behavior of the customer in the store. All the above-mentioned parameters play a major role in shaping the purchase intention and determining the consumer behavior of the customer. On the basis of these variables, the following hypothetical model explaining the antecedents of the overall retail shopping value and its consequential effects on different intentions is proposed. The hypothetical model would be able to determine the purchase intention of the customer and investigate the consumer behavior (Erkan & Elwalda, 2018).

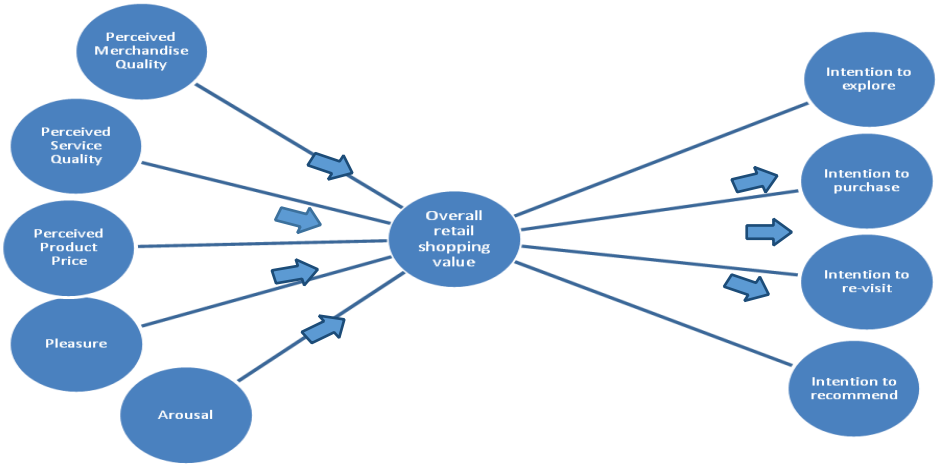

Figure 2. Proposed Model to Determine Retail Shopping Value

The above-depicted model can be tested using behavioral modelling techniques like structural equation modelling and neural modelling. Usage of neural modelling would result in more objectivity in predicting the determinants of retail shopping value, as well as the effects of this shopping value on measures of the consumers' intentions.

A genetic algorithm would be used to determine the best fit inputs for an artificial neural network model, thereby helping to predict the optimal consumer choices. A genetic algorithm and its usage ensures better accuracy and less complexity for presenting a clear decision criterion for varied consumer intentions. Hence, in order to implement this, a framework consisting of genetic algorithm with the proposed artificial neural network model will be taken into consideration in three stages as depicted in Figure II.

In the first stage, the input set will be taken into account, and the data reduction will materialize via feature selection, i.e. selecting a subset of the original predictive variables by excluding redundant variables, which have no or little predictive knowledge. This is done based on two objectives: increased accuracy and decreased parsimony. The neural network makes use of only the selected features both in learning and evaluation techniques; once it receives the subset of variables, it extracts predictive information from each of the selected subsets. In the mentioned approach, input features will be chosen by a genetic algorithm that will be expended to train the artificial neural network that predicts retail shopping value.

The second stage corresponds to implementation of an artificial neural network to implement the proposed model depicted in Figure II. The network will be designed, keeping in mind that the number of nodes at the input layer will correspond to the independent variables that are best determined by genetic algorithm in Stage 1. The output layer will have nodes corresponding to the dependent variables. This model will consist of a single middle layer. The demographics here can act as signals to the model. The network will be a feed forward network and will be given training using varied test signals. This will enable the adjustments of the weights of the network. The model will act as a futuristic paradigm to understand the response behavior of the customers in accordance with various cognitive factors.

In the third stage, an optimization process will take place to determine the optimal output from the set of outputs generated in Stage 2 from the corresponding artificial neural network. The proposed output nodes will be checked and tested to find the optimal output that can either overlap with the mutation or crossover as the genes combine to develop a new set of species that makes the best solution. Here, each output will be treated as genes of chromosome. The genetic algorithm, when applied at this stage, will deliver the most dominating intention of the customer for his purchase behavior, thus giving a better judgmental criterion for managers to use in targeting customers. Neurological judgements are based upon cognitive thinking adjudged by physiological parameters; therefore, in the present study, the neural network approach is suggested because it gives more objective and meaningful results. The neural models reduce the chances of behavioral subjectivity to the minimum, and the genetic algorithm helps the neural network model give more logical, accurate, and objective oriented results.

Conclusion

The study contributes by formulating a hypothetical model of consumer response behavior, which explains the antecedents of overall retail shopping value and, also, the different consequences of retail shopping value as measured in terms of the intentions of the customers. The model aims to judge the intentions of the customer using the neural networking approach. According to the model, the retail shopping value is constructed from five variables. These are perceived merchandise quality, perceived service quality, perceived product price, pleasure, and arousal, which will act as input layer in a neural network corresponding to independent variables. The output of the retail shopping value will be measured in the form of various intentions of the customer in a like manner, i.e. the intention to explore, intention to purchase, intention to re-visit, and intention to recommend. These consequences in the form of intentions will be measured as the output of the neural network model corresponding to dependent variables.

A genetic algorithm would be used to determine the inputs for the artificial neural network that best fits the model. A framework consisting of a genetic algorithm with the proposed artificial neural network model is taken into consideration in three stages. The genetic algorithm applied at all three stages would deliver the most dominating intention of the customer for his purchase behavior.

In the study, the usage of an artificial neural network (ANN) to provide an optimal solution was assumed to coordinate with a genetic algorithm (GA) in which the data obtained by the ANN will be processed and by using feed forward propagation that will be transferred to the GA, where this reduced data will again be reprocessed. Henceforth, the GA will optimize the best solution and resend it to previous output generator but now act as the input optimizer ANN. This cyclic propagation will definitely yield the optimality that will ensure accuracy and better prediction.

The study provides a novel approach to judging the retail shopping orientations and patronage behavior of customers by providing more accurate insights into the marketers through the usage of the proposed framework. The study also provides an incremental advancement in the field of behavioral prediction of the customer in retailing through the usage of technology. In a nutshell, it can be said that in today's age of digitalization of marketing, the suggestive paradigm shifts of measurement of shoppers' behavior and cognition through tracking of his neurological senses and genes will revolutionize the overall retailing scenario.

Theoretical and Managerial Implications

The paper provides theoretical implications to researchers, academicians, and scholars by proposing frameworks that add value to the existing pool of literature and directs them in a new direction. The variables mentioned in the proposed model can be tested and validated by future researchers. Therefore, the study contributes to the literature of genetic algorithms and neural networks in retail industry.

As far as the managerial implications are concerned, the field of artificial intelligence and genetic algorithms is gradually gaining momentum and credibility in the field of marketing. Genetic algorithms encapsulated with a neural network would let marketers make conclusions based on the decision criterion and result in informed, accurate, and precise decisions. Usage of genetic algorithms with neural networks to determine the most dominating customer intention from the retail shopping value would provide judgmental criterion for the managers to target customers.

The proposed model would help the marketers and retailers identify different cues associated with customer responses and shopping with more accuracy and ease. The model thereby acts as a futuristic model, explaining the response behavior of customers based on their measured cognitive factors.

Future Scope

The study designs and proposes a framework that gives us the optimal solution for predicting with high estimated accuracy. However, the context of the present study was propositional, as there is usage of artificial neural networks and genetic algorithms and their interaction with each other to provide optimal solutions. It was based upon the hypothesis derived from the logical conclusions, which were deduced from previous sets of literature. The study carries great scope in implementation of the framework, and further research should be conducted to make the framework operational and to apply it in real-world marketing decisions.

The arena of consumer response behavior is very wide, and different studies estimating this behavior have been performed in the past. Nevertheless, every research finally needs a comprehensive conclusion in the form of some assumptions that are logical derivatives of fragmented studies existing in the pool of research. Therefore, the study presents an opportunity for researchers to dive deeply into the framework and work on a hybrid approach which seeks to find most significant relationship and that is considered as the sole aim of the research.

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