

Neural Network Complexity Models for the Marketing Mix

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This essay is a statement of philosophy as much as (if not more than) it is a guide to technology. The technology is the application of artificial intelligence neural networks to marketing mix modeling. There is a compelling body of analysis which demonstrates the added value of neural networks when these neural nets are contrasted and compared to traditional regression type statistics.

Philosophically, there is almost a *need* to, at the very least, examine the implications of analysis methods such as neural networks. Marketing mix modeling is a problem of understanding a specific aspect of consumer behavior. Consumer behavior is a decision system of grand intricacies and elaborate amalgamations. Work over a variety of disciplines - ranging from molecular biology to particle physics and extending into the social sciences of economics and psychology - points to a new view of the progress of systems. This view passes the deterministic approach upon which we have traditionally relied, and leads us to examine the changing *interactions* that comprise the natural structure of a system ---- a consumer decision.

Modeling

To frame modeling in the context of media accountability, we do not have to search far. Much is available; in fact just a review of Broabent (1,2) offers a full perspective of the importance of accountability and the contributions of modeling to understanding media effectiveness.

One of our largest and best known consumer services firms defines accountability as leadership. This definition, for them, is in the context of planning and decision making. For us, accountability in media is nothing if not leadership! We can easily use this definitional framework for our purposes to address accountability in media as the responsibility to understand the investment of resources and the returning value they produce. Taking the leadership role to this end is a perfect position for researchers and their models.

It is common practice to use models for a variety of research applications. Copy testing, consumer choice, advertising awareness, and other specific tasks have specific, well documented and validated models associated with them. Of relatively more recent interest (and methodologically generalizable) is a class of market response models collectively known as marketing mix models. Roughly these models are defined by their practitioners to measure various effects of price, promotion, advertising, and competitive influence on a brand share or unit sales. While a variety of assumptions envelop the

field, the methods of modeling are, in general, quite similar. A review of the literature, finds primarily ordinary least squares based models, as well as structural equations, logit, and certain rule based systems (3,4).

One common trait in most of the marketing mix models used commercially, is a required assumption of either a linear or a predetermined simple nonlinear (e.g. logistic) relationship between the marketing mix inputs and the predicted target of sales or share. Additionally some of these models go to great lengths to remove the joint impact of the marketing actions of the marketplace. Particular variables which are often related to other model inputs, (say advertising awareness and advertising content) may be omitted in an effort to satisfy statistical requirements -- often at the expense of completeness and intuitive sensibilities.

There is ample justification for these current methods. In large part these models mirror the traditional methods applied over time by analysts in fields such as psychology, biology, economics, and others. And, it is just this type of analogous problem definition across fields that has facilitated any number of successful trends in analysis. *(This trend also should be closely followed now as new science emerges.)*

Additionally, modeling of marketing mix elements has grown successfully over the last few years. This success stretches across a range of product categories and data sources (scanner; household panel; etc).

This is a great start. Now in our leadership role, researchers have an opportunity to move the state of this art forward once more.

New thinking by economists on the nature of dynamical systems provides a map for restating marketing mix models. This approach, known as the complexity prospective or Santa Fe (after the Santa Fe Institute research center) prospective, sees an economy or market determined by the interaction of many dispersed, possibly heterogeneous, variables acting in parallel.

Using this archetype, we examine the benefits of applying neural networks to a variety of marketing mix tasks. By assuming the interaction of marketing elements, a very real picture of consumer response emerges. Neural networks recognize, accept, support, and nurture the notion that all elements of the marketplace interact. These interactions within the marketing mix and the related environment collectively are the antecedents of consumer behavior.

Intuitively, it is realistic to expect any consumer purchase decision is the result of the convergence of the relevant (to each individual consumer) elements of the marketing mix, e.g. product image, price, ad influence, etc. Models designed with neural networks are mathematically attuned to this type of relationship.

Complexity

A market place in motion is one of the most prominent of the many advantages we hope to realize by thinking in the complexity perspective. Our current models, by their nature, provide a descriptive view of events.

Following the path of science in general (if we can ever say there is agreement here!), modeling efforts in consumer behavior will move to reflect the living nature of decision making. Just as the specifics of economic modeling are changing from a mechanistic point of view to a point of view actually described as *organic* (5), so too should the models of the marketing mix reflect this change.

At the heart of these changes is the developing understanding of complexity. Waldrop (6) best describes the way research in this field casts a wide net to find a commonality of answers for a range of questions such as this summary:

- Why did the Soviet Union's forty-year hegemony over eastern Europe collapse within a few months in 1989?
- Why did the stock market crash Monday then 500 points on a single Monday in October 1987?
- Why do ancient species and ecosystems often remain stable in the fossil record for millions of years --- and then either die out or transform themselves into something new in a geological instant?
- How did a primordial soup of amino acids and other simple molecules manage to turn itself into the first living cell some four billion years ago?
- And perhaps most fundamentally, why is there something rather than nothing?

While the mechanics and structural answers to the above remain unknown, there is progress in an analysis method that applies to each and every one of these questions. In short order, each question concerns a system that is *complex*. That is, complex in the sense many elements or agents are acting and interacting in a variety of modes. These interactions then set the stage for the system to undergo spontaneous *self-organization*. Each group seeks collective properties that may not be reflective of the individual traits of group members. And, faced with new events, these systems are adapt. Just as the human brain constantly reorganizes its internal connections to learn from experience, all non mechanical systems follow a similar process.

This is the essence of the new perspective. Complex, self-organizing, adaptive behavior is predominate in physical and social systems (7).

Consumer behavior fits comfortably into this rubric. Marketing mix models are models of consumer behavior. Terminology of the process can obscure the notion of the response we are measuring. Often we speak of “the impact of price change on *sales*, coupon effect on *sales*, and advertising influence on *sales*”. But, what we are truly looking for is “how do all of the elements in the marketplace interact in the complex, self-organizing, adaptive system that is each individual consumer’s mind?”.

Neural Networks

In order to accurately model a complex adaptive system, we move beyond traditional methods.

Neural network complexity models contribute to the marketer’s process by accurately reflecting the workings of the marketplace. This technology is currently the most accessible to our purposes.

Neural nets were originally conceived to understand human brain function. Quickly, it was seen that we lack the computer capacity (by orders of magnitude) to approach the long sought “artificial brain”. However, this early research led to exciting discoveries that small scale, well defined problems can be addressed in a learning fashion that is not at all dissimilar to human trial and error learning.

Generally, neural networks are structured as a set of non linear processing units (neurons) arrayed in layers. The typical model has three layers. One layer is for the input of the observed variables with a separate unit to process each variable. A second layer, which is referred to as the hidden layer, is comprised of some number of additional neurons. This hidden layer associates input (variables) from the input to each other as well as to the final layer in the model. Completing the neural network model structure is the third layer ---- the output. In the third layer there is one neuron for each output or dependent variable in the model.

This characteristic form of connected neurons then reviews and learns the patterns present in a set of historical data. That learned knowledge is then available for generalization to new situations. Modeling in this manner provides a true non linear representation of a behavior (in our case, the marketing mix). Additionally, this modeling method facilitates an understanding of the dynamics in the data by observing through simulation how changes in any one input variable will interact with other inputs and affect the response of the model.

In the current discussion it is the approach to data form that is important. Specifics of the mathematics of neural networks are now widely available. Gruca and Klemz (8) present an excellent and concise guide to implementing these models.

Neural networks have their beginnings in the biological domain. For our purposes, this idea has taken on a form and personality all of its own. Reasons to employ neural nets for this task are gleaned from a rich pool of computational abilities. They include: no assumption of independence among the independent variables; the unknown shape of the distributions and relationships; to other access to the hidden conditional probabilities.

Marketing Mix

Implications for improvement in the implementation of marketing mix analysis are vast. Complexity assumptions are in line with an intuitive examination of the activity surrounding sales volume. All of the marketing mix components interact with each other in an emerging cohesion to drive product sales. Simulation of level changes in any mix variable will account for both the direct and interactive impact of a specific change.

Compared to traditional methods, there is a basic difference in interpreting the neural network complexity models themselves. The components of a traditional model, such as the variable coefficients are subject to tests for significance, relative impact, and direction. Examining the magnitude of each coefficient provides direct measure of importance. These simple models therefor are easily described with a well known set of statistics.

In corresponding neural networks no such statistics exist. The operation on the model is the basis for interpretation. It is useful to remember the reason that current traditional approaches were adopted was primarily due to the relative ease of computation, and the difficulty of conceptualizing the elaborate interactions and non linearity of the true nature of the data we analyze. This compromise also resulted in a general understating of the individual impact of marketing mix variables on total sales (9).

No longer must we continue to be confined by barriers to a complete understanding of the drivers of our businesses. The influences of a consumer's decision to purchase at a given time can be understood at the level where the power of marketing resource allocation is applied. We know the decision is a *complex dynamical system*. Technology has solved the problems of limited computational capability. Building on the work in all disciplines which are searching for order and examining complexity, consumer research will now take its place in the application and contributions to this newest scientific method.

To meet the demands of our leadership responsibilities to the rigors of accountability, we must employ the techniques and methods most aligned with the realities of the marketplace. Neural network models conceived as complex systems realize that aim.

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