Chapter 2.23
Extracting Knowledge from Neural Networks

Christie M. Fuller
Oklahoma State University, USA

Rick L. Wilson
Oklahoma State University, USA

INTRODUCTION

Neural networks (NN) as classifier systems have shown great promise in many problem domains in empirical studies over the past two decades. Using case classification accuracy as the criteria, neural networks have typically outperformed traditional parametric techniques (e.g., discriminant analysis, logistic regression) as well as other non-parametric approaches (e.g., various inductive learning systems such as ID3, C4.5, CART, etc.).

In spite of this strong evidence of superior performance, the use of neural networks in organizations has been hampered by the lack of an "easy" way of explaining what the neural network has learned about the domain being studied. It is well known that knowledge in a neural network is "mysteriously" encapsulated in its connection weights. It is well accepted that decision-makers prefer techniques that can provide good explanations about the knowledge found in a domain even if they are less effective in terms of classification accuracy.

Over the past decade, neural network researchers have thus begun an active research stream that focuses on developing techniques for extracting usable knowledge from a trained neural network. The literature has become quite vast and, unfortunately, still lacks any form of consensus on the best way to help neural networks be more useful to knowledge discovery practitioners.

This article will then provide a brief review of recent work in one specific area of the neural network/knowledge discovery research stream. This review considers knowledge extraction techniques that create IF-THEN rules from trained feed-forward neural networks used as classifiers.

We chose this narrow view for a couple of important reasons. First, as mentioned, the research in this area is extraordinarily broad and a critical review cannot be done without focusing on a smaller subset within the literature. Second,

classification problems are a familiar problem in business. Third, creating basic IF-THEN rules from a trained neural network is viewed as the most useful area in the entire research stream for the knowledge management and data mining practitioner.

With this narrow focus, some aspects of knowledge extraction from neural networks are obviously not mentioned here. With the focus on deterministic IF-THEN rules, outputs that include "fuzziness" (fuzzy logic) are omitted. In addition, research that involves different neural network architectures (e.g., recurrent networks) and/or different knowledge discovery problem areas (e.g., regression/prediction rather than classification) are also excluded from the review.

BACKGROUND

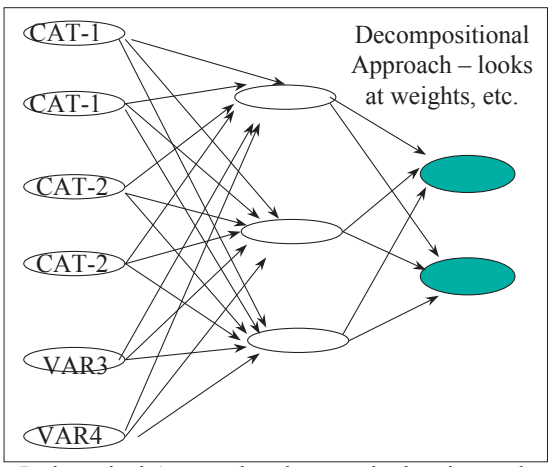
The discussion of the different neural network knowledge extraction techniques are organized around the fundamental premise or process used for rule extraction. Previous researchers (including Tickle, Maire, Bologna, Andrews, & Diederich, 2000) have used the following terms to help segment the different approaches: decompositional, pedagogical, and eclectic.

Decompositional techniques for rule extraction are approaches that perform rule extraction at the individual neuron (or neural component) level. Pedagogical approaches, on the other hand, extract knowledge by treating the entire NN as a "black box," creating rules by correlating inputs to the neural network to the resultant outputs (without considering anything about the structure or weights of the NN). It is reasonable to think of these two terms as extreme points in a continuous spectrum of approaches. Eclectic approaches are techniques that borrow some aspects from each of the two extremes.

Figure 1 helps visualize how these algorithms work. Figure 1 shows a 6-input, 3 hidden neuron, 2 output neural network. Assuming no bias inputs and a fully connected neural network, there would be 24 connection weights (not shown) which represent the knowledge stored in the neural network (after, of course, the NN has been trained on a set of data). The decompositional approaches will examine (at least) the connection weights that lead to each hidden neuron and will "discover rules" such as IF X2 < 7, THEN CONCLUDE Class A. Pedagogical approaches would present systematic random inputs to the neural network, observe the output of the neural networks, and "learn" rules like above through studying the relationship between input and output variations.

The review of pertinent neural network rule extraction algorithms also will include three different measures of technique usefulness (accuracy, fidelity, and comprehensibility) when such measures have been studied. These three different measures of technique usefulness are important in assessing the quality of the different methodologies. Accuracy measures the ability of the derived rule set to classify cases from the problem domain. This is typically reported as percentage correctly classified. Fidelity measures how well classification of cases using rules extracted from

Figure 1.



Pedagogical Approach – does not look at internal weights – just inputs and outputs