LEARNING SYSTEMS AND THEIR APPLICATIONS: FUTURE OF STRATEGIC EXPERT SYSTEM

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ABSTRACT

"Learning" denotes that a system is capable of adapting to a task, such that when the task is repeatedly performed the system will perform the task more efficiently than on previous attempts. Learning system may incorporate neural networks, fuzzy logic, genetic learning, self-learning expert systems, or a combination of any or all of these technologies. These systems are capable of the self-generation of mathematical, logical, or analytical rules for determining desired outputs based upon some input criteria or user assistance. Some of these systems are self-training; others require training and/or previous knowledge in order to learn. Learning systems can be hardware or software-based, or a combination of both. Today, a great deal of research incorporating machine-learning techniques continues in the area of Artificial Intelligence. The purpose of this paper is to discusses their strategic applications, advantages and problems of learning systems, then focus on how these technologies are being used for developing solutions to difficult, yet strategic decisions, and finally present recommendations for how future systems will have to differ from current systems.

Keywords: Learning Systems, Neural Networks, Fuzzy Logic, Self-Learning expert Systems

LEARNING STARTEGIES

Learning Strategies will typically fall into one of the following five categories of learning paradigms (1) Supervised Concept Learning, (2) Conceptual Clustering, (3) Analytical Learning, (4) Genetic Algorithms, and (5) Connectionist learning. (Derge, 1992) Supervised concept learning is the most mature of the learning paradigm, and not surprisingly, has had the most applications to date. The primary difference between conceptual clustering and supervised learning is that conceptual clustering systems must recognize the similarities between the training sets, and cluster these groups in accordance with a pre-established notion of similarity. Analytical learning attempts to speed the learning process by improving the goal searching method. Genetic algorithms utilize adaptive search methods, based upon the Darwinian concepts of "survival of the fittest." Connectionist learning evolved out of the study of "perception," and is a neural based learning paradigm utilizing massively parallel back propagation learning algorithms.

LEARNING TECHNOLOGIES

Four state-of-the-art learning technologies are discussed in this paper. These are Neural Networks, Fuzzy Logic, Genetic Learning, and Self-Learning Expert System. Each of the above technologies are gaining rapid acceptance across the globe as more and more applications are implemented using these technologies and are discussed below along with their operations, advantages, and disadvantages.

Neural Networks

The development of neural networks was initiated decades ago, in an attempt to mimic the process of the human brain. Neural networks typically require tens, hundreds, or even thousands of passes of the data sets before accurate classification can be accomplished. Once the network is trained and "good" results are determined, the neural network can usually perform pattern recognition, classification, or generate predictions on data that the network has never "seen" before. Table 1 given below, differentiate and exemplify the major differences between neural networks and expert systems (Samdani, 1990).

Table 1: Neural Nets Vs. Expert Systems

Neural Networks	**Expert Systems**
Example Based	Rule Based
Domain Free	Domain Specific
Finds Rules	Needs Rules
Little Programming	Much Programming
Easy to Maintain	Difficult to Maintain
Fault Tolerant	Not Fault Tolerant
Needs a Database	Needs a Human Expert
Fuzzy Logic	Rigid Logic
Adaptive System	Require Reprogramming

Neural networks have an additional advantage over other learning system, in that they are fault tolerant; neural nets can have node failures and still generates "good" results. Table 1 above states that neural nets need a database and expert systems need a human expert. Self-learning expert systems will make use of a database as well, and many case-based expert systems will also utilize a database. In these instances, an expert system requires an interface to data set storage. One may also have the ability to load applications specific pre-trained neural net parameters into the neural net, eliminating having to repeat the training process. Also, self-learning expert systems will require a human expert, but perhaps only for the initial design of the rule base, and then to supervise the process of the learning process. Neutral networks have been used in hundreds of applications: assisting in process control applications, stock market forecasting, real estate sales forecasting, pattern recognition, and many other diverse application areas.

Fuzzy Logic

Fuzzy logic employs mathematical relationships to determine a solution to a target problem. However, unlike conventional solutions that yield one precise solution to a problem, fuzzy logic allows some tolerance 9or overlap) between possible solutions. Solutions to some problems are defined as "membership groups" In operation; fuzzy logic is used in conjunction with a rule based. Rules examine the input criteria, compare this to the desired criteria as determined by the rules, and then determine the error that exists between input and the desired target. This may result in a solution that is between membership functions. In these instances, the area under the curve between the error function and the membership function is computed for both membership functions. The centroid (center of gravity) is typically computed on the overlapping areas, and this value is used for feedback into the system. Such a process is called "defuzzification", and calculation of the centroid is just one example of an algorithm used for accomplishing the defuzzification process.

A classic problem solved by fuzzy logic controller problem of balancing the inverted Pendulum. One such solution uses a hardware implementation for defuzzification (a defuzzifier chip), and a rule base-controlled (consisting of only 7 rules) fuzzy controller. Feedback from a position sensor is fed to the fuzzy controller, where the correction signal is computed and fed to a DC servomotor, which quickly corrects the position of the base containing the unbalanced pendulum. Fuzzy systems, although becoming extremely popular in real-time control systems, have the advantages of overcoming noisy data sets, but the disadvantage in being used as a broad solution-solving tool, especially in those areas where tolerances are not permitted.

Genetic Learning

Genetic learning attempts to develop a model of a problem by applying possible solutions to a target problem. A user-defined evaluator then determines how well the solution has "fitted" to the target problem (note that the evaluator is an algorithm), using "survival of the fittest" methods. That is, if a generated solution is not well fitted for the target, it is killed. If a solution is a good fit, it survives. When a solution survives, it is then placed in a "gene pool,' similar to biological genetics, where other "good" solutions are placed. These solutions are then mutated and/ or mixed with other "good" solutions in an attempt to create even better solutions.

Self-Learning Expert System

Most self-learning (or adaptive) expert systems are supervised learning systems. The most common self-learning expert systems derive their rules based on a-priori information. The system repeatedly guesses and improves upon its rule base, depending upon whether the guesses were in the right or wrong direction. Eventually, the rule base is adjusted such that the logic of the inferences is able to handle all situations presented to the system. Thus, adaptive expert systems alter their execution based upon past experiences. In operation, there are many methods used to assist an expert system in adaptation. One could implement optimization methods for decision tree adaptation (pruning), monitor histograms of rules and various inferences and adjusted probabilities of decision search paths accordingly, etc.

The advantages of such a system are obvious – rules that have a higher frequency of occurring are the first rules tried in a decision search. However, the disadvantages are glaringly obvious as well: what if the system has some highly critical nodes that should always be searched first? It is true that the system developer would hopefully remember to permanently keep such nodes enabled, but then the system is not fully optimized for searches. Self-learning systems may be highly recursive – if no goal is reached, then the existing success/failure ratios can be continuously modified by the system in an attempt to reach a highly probable goal. There has been a great deal of success with self-learning expert systems in many process control and industrial applications, but these systems are typically found in conjunction with one or more of the aforementioned technologies such as neural networks, fuzzy logic systems or genetic algorithms.

INTEGRATING LEARNING TECHNOLOGIES

Some of the most successful applications in recent research indicate that self-adaptive systems are being implemented utilizing one or more learning technologies. This implies that expert systems are being coupled with neural networks, fuzzy logic control, and genetic learning. The advantage of coupling several learning technologies together is obvious: by integrating several learning technologies, one can create a system that maximizes its learning potential, capitalizing on the advantages of several different learning strategies. An example would be a system that utilizes a neural network and a genetic learning algorithm. Recall that a neural network typically converges rather slowly upon its solution, requiring several passes of training data sets in order to determine the correct weights for the desired solution. The addition of the genetic learning algorithm provides a more rapid convergence on the weights, which can be used by the neural network. An expert system could be added to determine when the genetic algorithm needs to be invoked, adding an additional level of optimization. In this instance, the expert system could determine the mean-squared-error between the desired output criteria of the neural network and the actual output. Depending upon a tolerance or error threshold level, the expert system could decide to call upon the genetic learning algorithm for the determination of better weights, which could then be used by the neural network, or allow the neural net to continue on its current course of confluence. It would even be possible to add a fuzzy logic system into this configuration to assist in determining the output error criteria, if the decision domain were difficult to define or if the real-time control would be necessary.

One example of such a system is a product called NET-Link+ by Norrad (located in Nashua, N. H.), which interfaces an expert system with a neural net, fuzzy logic, and genetic learning in order to identify optimal telecommunication routes in real-time:

> "You are no longer limited to a single (learning) paradigm. You can use neural networks for what they do best, fuzzy logic for what it does best, .. and genetic algorithms for what they do best, all in the same application." (Johnson, 1991)

Such highly integrated learning systems do not need to be extremely expensive, even for real-time applications. It is possible to use a PC-based platform, interfaced with transputer boards (computers are high speed coprocessors that are on single cards which can be placed into the PC back plane), for a real-time fully integrated learning system with capabilities of all learning systems running in parallel including the expert system; each transputer board would run its own application. Blackboard interfacing schemes (blackboards are commonly used with multiple expert systems that need to access real-time data) could be utilized, and all system could access the data simultaneously.

Integrated learning systems could also be used in decision support systems for many predictions and forecasting tasks. Highly integrated learning systems offer the best of all current state-of-the-art learning paradigms, and should certainly be considered for automated decision system of the future.

APPLICATIONS OF LEARNING SYSTEMS

Last decade has seen incredible growth of Expert Systems incorporating intelligent algorithms. The penetration of Information Technology in business world has enabled technologies like ANN, Fuzzy Logic and Genetic Learning to solve complex business problems. The latest applications of ANNs and Fuzzy Logic are emerging in all industries including medicine and chemistry. (Selén, 1998 and Virtanen, 1999) VTT Information Technology with participating companies like Valio (Finland's largest dairy company), Kesko (Finland's largest wholesales company) and ICL Data developed the Intelligent inventory control (VTT-PROMISE) system. The VTT-PROMISE project was concerned with the forecasting of product sales for companies operating in the consumer market, by using an intelligent software tool. The goal was to prepare the forecasts as automatically as possible, and in time spans consistent with the business processes of the companies. The results seem promising but genetic algorithms haven't been incorporated in the actual system due to sensitivity problems. A new method for the combination of weekly and monthly forecasts has been developed (Karanta, 1999).

Another work conducted on similar lines was to utilize adaptive and intelligent methods especially for signal processing related applications. The group of companies involved was Nokia Research Center (speech coding and recognition, image interpolation, bar-code recognition), Nokia Mobile Phones (channel equalization), Oy Imix Ab (enhancement of digital x-ray images) and Patria Finavitec Systems (passive detection of moving targets). The following applications were considered: speech recognition, speech coding, image interpolation, bar-code recognition, channel equalization, enhancement of digital x-ray images and passive detection of moving targets. (Kantsila, 1999 and Salmela)

Another latest research is use of neural algorithms for radio communication systems. The novel-decoding algorithm for convolution codes has been derived at the Nokia Research Center. It uses a recurrent neural network, which has some similarities to the Hopfield network. The network is dependent on the code structure and has to be derived for each code separately. The performance of the codes has been verified using extensive computer simulations. The studies on detection in a hostile environment concentrated on using self-organizing networks (SOMs). The main finding was that neural methods might provide improved performance in detection problems where nonlinearities are involved. (Raivio, 1997)

Genetic Algorithm is making its own niche in the intelligent systems world. In the past few years GAs has shown their capability in advanced subjects like physics and economics. In the field of physics the important application is calculation of bound states and local density approximations. In Economics Genetic Algorithm has found its way in the Game theory (study of multi-person decision problems). (Chughtai)

Fuzzy logic is also making its mark in the intelligent systems domain. Few applications which have made difference are Automatic control of dam gates for hydroelectric-power plants, Simplified control of robots, Substitution of an expert for the assessment of stock exchange activities, Efficient and stable control of car-engines, Cruise-control for automobiles, Improved efficiency and optimized function of industrial control applications, Recognition of handwritten symbols with pocket computers, Controlling of subway systems in order to improve driving comfort, precision of halting and power economy and Improved safety for nuclear reactors. One of the most successful fuzzy logic implementations is the control of subway in Sendai, Japan. The fuzzy system controls acceleration, deceleration, and breaking of the train. Since its introduction, it not only reduced energy consumption by 10%, but the passengers hardly notices now when the train is changing its velocity. In the past neither conventional, nor human control could have achieved such performance (Soylemezogolu).

Fuzzy molecular modeling (FMM) is the application of fuzzy logic to molecular modeling. Typically, to model a chemical's structure, lattice parameters and a coordinates table (such as the Wyckoff coordinates for a chemical compound under examination) are needed. Together, the lattice parameters and Wyckoff coordinates provide enough information to create a three-dimensional (3-D) structure of a compound's unit cell. However, the measurement of lattice parameters is subject to variability from one experiment to another. The fuzzy lattice parameters are created by searching the literature for experiments performed under the same conditions and then extracting the minimum, average, and maximum values for each lattice parameter. The end result is a fuzzy unit cell, with fuzzy bond lengths and fuzzy bond angles, that incorporates the variability found in literature. However, two interesting phenomena arise in creating fuzzy unit cells, the concept of fuzzy lines and fuzzy vertices. By using fuzzy lattice parameters, it is possible to express other characteristics of the unit cell in imprecise terms, thereby providing researchers with possible ranges for characteristics of interest. This has the added benefit of providing variable information that can help simplify a decision of selecting a specific compound out of a selection of many. [Ress , Wyckoff, 1993]

The opening of Finland's National Electricity Stock Market (EL-EX) a few years ago made possible for electricity companies to trade their own production easily with other companies and large-scale consumers. Prediction of future consumption in few next day scales can give a great advantage in both purchasing and selling electricity. To make this forecasting possible, an Expert System project was conceived. The aim of this project was to study the possibility of predicting consumption in particular distribution area using neural networks. A further aim was to design PC-software based on neural networks to help in the calculation and simulation of different conditions. The results so far achieved were: - analysis of different neural networks enabled the identification of the optimal network design. However, the difference between the results and realization must be quite small (less than 5 percentage units). The best model so far gave difference of between 0 to 8 % and an average difference of 4.5 %. Considering that consumption in Finland varies very much, result was satisfactory (Laitinen).

LEARNING SYSTEMS OF FUTURE

Learning systems of the future must incorporate and take advantage of all paradigms. Expert system will certainly be the key to success for future self-adaptive systems. A decision support system that allows for the integration of multiple expert systems, multiple learning paradigms, relational database technologies, and support modules that include natural language processing, hyper-technologies, statistical support, reporting modules, object-oriented code development, object linking and embedding, dynamic link libraries, 4GL's, etc. will be essential support functions of the future systems. Future systems must be capable of allowing additional applications-specific expert systems to be easily integrated and provide utilities for the development of expert systems. The expert system manager (EMS) would provide an intelligent front-end to the decision support system. It would be capable of monitoring the execution of several applications-specific expert systems (ASES), and have black boarding capabilities for real-time data evaluation and sharing. The ASES's would be adaptive systems, and have a multitude of low and high level adaptive learning algorithms at their disposal.

Automated knowledge acquisition, a system's capability of extracting knowledge from a user and generating the associated data and rules, will be another feature that learning systems of the future will include. This feature would streamline expert system development and allow "unknown" data types, attributes, or objects to be realized by the system via the user's input, or by searching through existing databases. All levels of organizations would use future adaptive systems, since their flexibility will allow users to communicate, share data, and solve problems in the most efficient way possible. Intractable problems, unforeseen trends, new methods of Research and Development, and more knowledgeable approaches to decision making are only a few of the benefits that will be realized from future adaptive systems.

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