Abstract

Artificial Neural Networks (ANNs), which fall under the Artificial Intelligence (AI) methodology, have enjoyed a recent revival in interest associated with advances in computer technology. While ANNs were originally developed to model the biological behavior of brain cells call neurons, recent years have seen them applied in such diverse areas as detecting bombs in airports, cancer cells in pap smears, fraud in credit card transactions, schizophrenia in mental patients, heart attacks, and foreign exchange forecasting. This thesis examines the viability of applying ANNs to problems in the finance domain using Australian financial data. The research focuses on two particular areas: predicting distress in credit unions of New South Wales and modeling the Australian/US dollar foreign exchange trading systems. The thesis examines the methodologies involved in applying ANNs to these problems as well as comparing their results with those of more conventional econometric methods

1. Introduction to Artificial Intelligence and Artificial Neural Networks 1.1 Introduction here can be little doubt that the greatest challenge facing managers and researchers in the field of finance is the presence of uncertainty. Indeed risk, which arises from uncertainty, is fundamental to modern finance theory and, since its emergence as a separate discipline, much of the intellectual resources of the field have been devoted to risk analysis. The presence of risk, however, not only complicates financial decision making, it creates opportunities for reward for those who can analyze and manage risk effectively. By and large, the evolution of commercial risk management technology has been characterized by computer technology lagging behind the theoretical advances of the field. As computers have become more powerful, they have permitted better testing and application of financial concepts. Large-scale implementation of Markowitz’s seminal ideas on portfolio management, for example, was held up for almost twenty years until sufficient computational speed and capacity were developed. Similarly, despite the overwhelming need from a conceptual viewpoint, daily marking to market of investment portfolios has only become a feature of professional funds management in the past decade or so, following advances in computer hardware and software. Recent years have seen a broadening of the array of computer technologies applied to finance. One of the most exciting of these in terms of the potential for analyzing risk is Artificial Intelligence (AI) and, Artificial Neural Networks (ANNs), which in combination with other techniques, has recently begun to gain prominence as a potential tool in solving a wide variety of complex tasks. ANNs differ from AI as it is a contemporary machine T Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 3 learning technology and does not have many of the characteristics of traditional AI (e.g. symbolic processing and use of knowledge base). ANN-based commercial applications have been successfully implemented in fields ranging from medical to space exploration. This thesis focuses on a development of a different kind. The applications of ANNs to problems in finance is a reversal of the traditional role between technology and theory. To the extent that ANNs reflect a conceptual approach to problems, they provide a context in which computer technology may well precede rather than lag behind theory. Indeed, this thesis falls under a new interdisciplinary field in finance encompassing these new technologies and being collectively called computational finance. This field is gaining prominence as evidenced by the popularity of the first international conference dedicated to it, the Computational Intelligence in Financial Engineering Conference which was held in New York in 1996, bringing together researchers from a diverse background, ranging from banking to biology and engineering to physics, all with the common interest of applying their field of expertise to finance. The Oregon Graduate Institute of Science and Technology has now introduced a postgraduate degree in computational finance as an alternative to a traditional MBA which they described as “a 12 month intensive program to train scientists and engineers for doing state-of-the-art quantitative or information systems work in finance”. 1.2 Thesis Topics The major focus of this thesis is the application of artificial neural networks to the field of finance with an Australian context. The thesis offers an intuitive interpretation of ANNs, how they can be applied in finance, and their relationship to more conventional statistical techniques. In particular, it demonstrates how ANNs can be applied to financial classification and financial time-series forecasting tasks in the Australian financial market. Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 4 Specifically, it demonstrates the application of ANNs to two problems in finance; firstly, forecasting financial distress among financial institutions in New South Wales, and secondly, a foreign exchange trading simulation of the Australian dollar/US Dollar exchange rate with an ANN-based trading system. Chapter 1 introduces the idea of Artificial Intelligence and Artificial Neural Networks and their role in finance. Examples of commercial application of ANNs are also provided. Chapter 2 provides the background material on ANN. Specifically, it traces the development of ANNs from the late nineteenth century to the present time, discusses the strength and weaknesses of using an ANN, its basic structure and the procedure for constructing it. Chapter 3 provides a more in depth discussion of ANNs from the technical and statistical aspects. The chapter discusses the neurodynamics or the properties of an individual artificial neuron and the architecture of ANNs. In addition, the XOR problem; an example of a non-linearly separable problem that could not be solved by early ANNs programs; as well as one of its solutions, the backpropagation learning algorithm, are presented. A summary comparison is made between ANNs and the statistical methods, as well as the similarity between both models and the terminology used in both fields are discussed. Chapter 4 examines the viability of using ANNs to develop an early warning predictor of credit union financial distress. An earlier version of this chapter [Tan 1996], has been published as a chapter in a book by Trippi and Turban [1996]. The credit union failures of the eighties have resulted in the tightening of supervision of credit unions in Australia, culminating with the formation of a Federal regulatory body, the Australian Financial Institution Commission (AFIC), to oversee the non-banking institutions. The data and the study are based on earlier work in this area by Hall and Byron [1992] who conducted the Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 5 initial research for AFIC. Although the Hall and Byron models are not used by AFIC currently, a model that has the ability to identify credit unions that may fail at an early stage, allows AFIC to allocate their resources more efficiently and take the necessary actions if required, to avert a financial disaster from happening. Potential credit unions in trouble are usually put under supervision and if required merged into stronger credit unions. This research examines the viability of using ANNs as an early warning predictor of financial distress in credit unions of New South Wales. A direct comparison of the results obtained from using ANNs to the Hall and Byron’s Probit model is made followed by a discussion of the results. The ANN model is found to perform marginally better than the Probit model. The chapter concludes with a criticism of the current methodology and suggest improvements as well as directions for further research in this area. Chapter 5 discusses the application of ANNs to the foreign exchange trading, focusing on trading simulations in the foreign exchange market, in particular, the USD/AUD market. An earlier version of this chapter had been presented as an invited expert paper by the author at the TIMS/INFORMS ‘95 conference at Singapore in June 1995 [Tan 1995a]. Portions of it was also presented at the Ph.D. Economics and Finance Conference at Perth in December 1995 [Tan 1995b]. Although there have been studies made in this area before, most of the studies either assume very simplistic transaction costs or assume no transaction costs at all. Transaction costs are very important in determining the viability of a trading system as in many cases, they can reduce the profitability of a trading system significantly. All the simulations in this research take account of the interest differentials and financial transaction costs. Comparison of the ANN-based trading system is made against the traditional time-series autoregressive (AR)-based system. The chapter introduces a simple ‘hybrid’ model, ANNWAR, that outperformed earlier trading models, Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 6 by combining ANN with AR results. It suggests that time arbitrage opportunities may exist in some financial markets and that these may be exploited by utilizing ANNWARs. Chapter 6 concludes the thesis with a summary of the findings in the thesis and identifies areas for further research. 1.3 Artificial Intelligence AI has been described as software that behaves in some limited ways like a human being. The word artificial comes from the Latin root words facere arte which means “make something”; thus AI translates loosely to man made intelligence. AI has been defined in many ways. Winston [1984] suggests one definition of AI as the study of ideas that enable computers to be intelligent. Rich and Knight [1991] define AI as the study of how to make computers do things which, at the moment, people do better. The following are some more common definitions and/or descriptions of AI: · AI is intelligent because it learns; · AI transforms data into knowledge; · AI is about intelligent problem solving; and · AI embodies the ability to adapt to the environment, to cope with incomplete or incorrect knowledge. While artificial intelligence techniques have only recently been introduced in finance, they have a long history of application in other fields. Experience to date across a wide range of non-financial applications has been mixed. Patrick Winston, a leading AI researcher and the head of MIT’s AI Laboratory, conceded that the traditional AI methods such as search methods, predicate calculus, rule-based expert systems and game-playing, have achieved little progress [Gallant 1994]. The problem domain that traditional AI methods seem to fail Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 7 in is in the trivial and common sense-type of tasks that humans find easy, such as recognizing faces, identifying objects and walking. Therefore, it was natural for AI researchers to turn to nature and the physical laws and processes for inspiration to find better solutions. As a result, many of the contemporary artificial intelligence tools developed in the natural sciences and engineering field have successfully found their way into the commercial world. These include wavelet transformations and finite impulse response filters (FIR) from the signal processing/electrical engineering field; genetic algorithms and artificial neural networks from the biological sciences; and, chaos theory and simulated annealing from the physical sciences. These revolutionary techniques fall under the AI field as they represent ideas that seem to emulate intelligence in their approach to solving commercial problems. All these AI tools have a common thread in that they attempt to solve problems such as the forecasting and explanation of financial markets data by applying physical laws and processes. Pal and Srimani [1996] state that these novel modes of computation are collectively known as soft computing as they have the unique characteristic of being able to exploit the tolerance imprecision and uncertainty in real world problems to achieve tractability, robustness, and low cost. They further state that soft computing is often used to find an approximate solution to a precisely (or imprecisely) formulated problem. Huffman [1994] of Motorola states that “At Motorola, we call neural networks, fuzzy logic, genetic algorithms and their ilk natural computing”. These contemporary tools are often used in combination with one another as well as with more traditional AI methods such as expert systems in order to obtain better solutions. These new systems that combine one or more AI methods (which may include traditional methods) are known as ‘hybrid systems’. An example of a hybrid system is the financial Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 8 trading system described in chapter 5 of this thesis which combines an artificial neural network with a rule-based expert system. Lawrence [1994] preferred to use the term computer intelligence to describe expert systems and artificial neural networks as she felt it was less misleading and less controversial in defining the “intelligence” emulated by such systems. 1.4 Artificial Intelligence in Finance 1.4.1 Expert System Financial analysis falls into the Expert Task Domain of AI as classified by Rich and Knight [1991]. Thus, it is not surprising that the most used AI methods in the financial field have been expert systems. An expert system is a program that is developed by a programmer, known as a knowledge engineer, who may have no domain knowledge of the task at hand, with the help of a domain ‘expert’ who may not have any programming expertise. The system is developed by trying to capture the human expert’s knowledge into a set of programming rules that assist in decision making. Hence, expert systems are often described (perhaps incorrectly) as rule-based systems1 . Expert systems have been used in medical diagnosis problems, fraud detection, prospecting and mineral detection. The biggest limitation of expert systems is that they require full information about outcomes and, therefore, deal poorly with uncertainty. 1 Today’s expert systems are, in actual fact, more object-oriented based than rule-based, with the advent of object-oriented programming (OOP) techniques and the advantages they offer. According to Turban et al. [1996, p. 593], rule-based systems refer to expert systems whose knowledge is solely represented as production rules; which are rules in the form of condition-action pairs: “IF this condition occurs, THEN some action will (or should ) occur.” Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 9 Recently, tools such as model-based reasoning and case-based reasoning have been developed to improve upon the rule-based expert systems. Model-based reasoning is based on knowledge of the structure and behavior of the devices the system is designed to understand [Turban 1993, p. 599-600]. As model-based systems incorporate a model of the device to be diagnosed, model-based expert systems are said to be able to reason from “first principles”. They are especially useful in equipment diagnosis problems as they are not limited to reasoning only from observable values. Since they are able to reason from first principles; that is, the systems have knowledge of the internal processes of the machinery; they can compute the state the machine is in rather than attempt to match the state a machine is in against complex symptoms (as in the case of rule-based expert systems). Another advantage of model-based systems is their “transportability” feature. For example, a rule-based system that incorporates an expert’s knowledge of troubleshooting problems with a particular computer may be useless in solving problems on different computers. A model-based system that has thorough working knowledge of digital circuits, on the other hand, can theoretically be used to diagnose the problem of any computer. Case-based reasoning basically attempts to solve new problems by adapting the solutions used to solve old problems. Case-based systems are suitable for problem domains that are already precedent-based such as law, medical diagnosis and claims settlement. Case-based reasoning improves knowledge acquisition as they are easier to build, simpler to maintain and less expensive to develop and support [Turban 1993, p. 602]. 1.4.2 Artificial Neural Networks in Finance From the range of AI techniques, the one that deals best with uncertainty is the Artificial Neural Network (ANN). Dealing with uncertainty in finance primarily involves recognition Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 10 of patterns in data and using these patterns to predict future events. Accurate prediction of economic events, such as interest rate changes and currency movements, currently ranks as one of the most difficult exercises in finance; it also ranks as one of the most critical for financial survival. ANNs handle these problems better than other AI techniques because they deal well with large noisy data sets. Unlike expert systems, however, ANNs are not transparent, thus making them difficult to interpret. This thesis demonstrates the methodology to set up and test two ANN-based applications in finance. In the strict sense, they are simple hybrid systems that combine the ANN methodology with simple rule-based expert systems. According to Zahedi [1993], expert systems and Artificial Neural Networks offer qualitative methods for business and economic systems that traditional quantitative tools in statistics and econometrics cannot quantify due to the complexity in translating the systems into precise mathematical functions. Medsker et al. [1996] list the following financial analysis task on which prototype neural network-based decisions aids have been built: · Credit authorization screening · Mortgage risk assessment · Project management and bidding strategy · Financial and economic forecasting · Risk rating of exchange-traded, fixed income investments. · Detection of regularities in security price movements · Prediction of default and bankruptcy Hsieh [1993] states the following potential corporate finance applications can be significantly improved with the adaptation to ANN technology: Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 11 · Financial Simulation · Predicting Investor’s Behavior · Evaluation · Credit Approval · Security and/or Asset Portfolio Management · Pricing Initial Public Offerings · Determining Optimal Capital Structure Trippi and Turban [1996] note in the preface of their book, that financial organizations are now second only to the US Department of Defense in the sponsorship of research in neural network applications. 1.5 Artificial Neural Networks Artificial Neural Network (ANN) models were inspired by the branch of biological sciences that studies how the neuroanatomy of living animals has developed in solving problems. According to Nelson and Illingworth [1990], ANNs are also called: · Parallel distributed processing models · Connectivist/connectionism models · Adaptive systems · Self-organizing systems · Neurocomputing · Neuromorphic systems Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 12 ANNs consist of many interconnected processors known as neurons2 that perform the summing function. Information is stored in the weights on the connections. More detailed discussion on the technical aspects of ANNs is given in chapters 2 and 3. An ANN mimics the human brain’s biological neural network. The biological neural network is the mechanism through which a living organism’s nervous system functions, enabling complex tasks to be performed instinctively. The central processing unit of that nervous system is known as a "neuron". The human brain has around 10 to 100 billion neurons, each connected to many others by "synapses". The human brain has around 100 trillion synapses. These connections control the human body and its thought processes. In short, ANNs attempt to replicate the learning processes of the human brain. The first ANN theories were expounded by researchers attempting to explain human behavior and the thinking process by modeling the human brain. To this day, many of the prominent researchers in the ANN field have a background in psychology. There are four distinct current areas of research in ANNs: · Using ANNs to model the biological networks in order to gain understanding of the human brain and its functions. This area is of particular interest to psychologists and researchers in neuroanatomy. · Using ANNs as an educational tool in order to gain understanding on how to solve complex tasks that traditional AI methodologies and computer algorithms have had difficulty in solving. Researchers in this area include computer scientists and engineers, who are mainly interested in constructing better computer algorithms by studying the problem-solving process of an ANN. 2 At the time of writing, there is still no standard terminology in the ANNs field. The neuron has also been called the following in the some ANNs literature: processing elements, neurodes, processors and units. Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 13 · Using ANNs to solve real world-types of problems in various commercial applications. Many researcher in this area have backgrounds in areas other than those related to ANN. The attraction of using an ANN is the simplicity in using it as a tool and the reported ANN-based commercial application successes. There are many ANN software packages that are user-friendly enough for new users to start using without requiring them to have an in depth knowledge of the ANN algorithms. This is unlike conventional computer techniques which require a user to thoroughly understand the algorithm before writing a program to apply it. In the case of ANNs, all a user needs to know is how to present the problem at hand in a form that an ANN can understand. · Improving ANN algorithms. Researchers in this field are interested in constructing better ANN algorithms that can ‘learn’ or model more efficiently; i.e. quicker training times and/or more accurate results. Research efforts on ANNs are being conducted on a global basis. Nelson and Illingworth [1991] state that Jasper Lupo, the deputy director of the Tactical Technology Office of the Defense Advanced Research Projects Agency (DARPA), called the neural network technology “more important than the atom bomb” [Johnson and Schwartz 1988]. According to Nelson and Illingworth, DARPA originally earmarked US$390 million for an eight-year neural network program but even when the original funding was reduced to US$33 million over 17 months, there were still many applications for the research grants. More recently, Turban and Trippi [1996], state that following the five-year research program, the Department of Defense (D.O.D) is planning to spend an additional US$15 million in neural network research over the period 1995-2000. They further claim that the Japanese have embarked on a 10-year, US$20 million program to further develop neural network technology, mainly in the commercial arena. Japan’s main ANNs research is sponsored by its government under its post-fifth generation computer program called “The Human Frontiers”. However, Japanese corporations are Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 14 already developing products based on ANNs. Examples of Japanese corporations involvement with ANN technology are: · Sharp Corporation’s optical character reading of printed Japanese program [Shandle 1993], · Nippon Steel’s casting breakthrough prediction program [Shandle 1993], · Hitachi’s ANN hardware system design [Shandle 1993], · Ricoh’s experimental neurocomputer that runs without software and acquires all computing capabilities through learning [Dambrot 1992], · Fujitsu’s ANNs-based mobile robot controller [Nelson and Illingworth 1991, p. 23], and · NEC Corporation’s neurocomputer [Nelson and Illingworth 1991, p. 23], etc. Europe’s ANNs research effort is called ESPIRIT II and is a five year project involving eight countries and several hundred worker-years of effort [Mehta 1988]. This has been supplemented by a new program announced by ESPIRIT in early 1989, known as the Application of Neural Networks for the Industry (ANNIE) [Newquist III, 1989]. Nelson and Illingworth [1991] state the following about ANNs research effort in individual European countries: · Germany has a US$250 million 5 year program [Johnson 1989b]; · France, probably has the most active development with six neural-based microchip projects in Paris alone [Johnson 1988]; · Netherlands research has moved from independent research to government sponsored and coordinated research; and Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 15 · United Kingdom has a US$470 million project. The UK Advisory Council for Science and Technology forecast the market for neural network products in 1997 at US$1 billion, a forecast which resulted in the UK Department of Trade and Industry (DTI) announcement of a Technology Transfer program that will invest 5.7 million pounds over the next three years to raise awareness of the benefits of neural networks to 6,000 UK companies [Milton 1993]. 1.6 Applications of ANNs Widrow, Rumelhart and Lehr [1993] argue that most ANN applications fall into the following three categories: 1. Pattern classification, 1. Prediction and financial analysis, and 1. Control and Optimization. In practice, their categorization is ambiguous since many financial and predictive applications involve pattern classification. A preferred classification that separates applications by method is the following: 1. Classification, 1. Time Series, and 1. Optimization. Classification problems involve either binary decisions or multiple-class identification in which observations are separated into categories according to specified characteristics. They typically use cross sectional data. Obviously, the interdependence of the observations need to be considered as most real world problems may contain observations that do not Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 16 fall directly into the defined categories. Solving these problems entails ‘learning’ patterns in a data set and constructing a model that can recognize these patterns. Commercial artificial neural network applications of this nature include: · Credit card fraud detection being used by Eurocard Nederland, Mellon Bank, First USA Bank [Bylinsky 1993], Visa [Classe 1995], ]; · Reducing credit card application processing time by processing scanned images of hand-printed data to machine readable text [Prince 1996]; · Prediction of vehicle driving comfort to assist engineers in the design process [Burke et al. 1996]; · Assisting targeting donors in fund-raising activities by predicting long term profitability of each donor on an organization’s house file [Yoegel 1996]; · An automated antivirus system for computer networks called Immune System, developed by IBM [Information Week 1996]; · Identifying property sites for retail outlets [Meall, 1996]. · Optical character recognition (OCR) utilized by fax software such as Calera Recognition System’s FaxGrabber and Caere Corporation’s Anyfax OCR engine that is licensed to other products such as the popular WinFax Pro and FaxMaster [Widrow et al.1993]; · Cursive handwriting recognition being used by Lexicus3 Corporation’s Longhand program that runs on existing notepads such as NEC Versapad, Toshiba Dynapad etc. [Bylinsky 1993] and Lexicus’s Chinese character recognition software [Hutheesing 1996]; 3 Motorola bought Lexicus in 1993 for an estimated US$7 million and the focus of Lexicus is now on developing Chinese writing recognition [Hitheesing 1996]. Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 17 · Cervical (Papanicolaou or ‘Pap’) smear screening system called Papnet4 was developed by Neuromedical Systems Inc. and is currently being used by the US Food and Drug Administration to help cytotechnologists spot cancerous cells [Schwartz 1995, Dybowski et al.1995, Mango 1994, Boon and Kok 1995, Boon and Kok 1993, Rosenthal et al.1993]; · Petroleum exploration being used by Texaco and Arco to determine locations of underground oil and gas deposits [Widrow et al.1993]; and · Detection of bombs in suitcases using a neural network approach called Thermal Neutron Analysis (TNA), or more commonly, SNOOPE, developed by Science Applications International Corporation (SAIC) [Nelson and Illingworth 1991, Johnson 1989, Doherty 1989 and Schwartz 1989]. In time-series problems, the ANN is required to build a forecasting model from the historical data set to predict future data points. Since the sequence of the input data in this type of problem is important in determining the relationship of one pattern of data to the next, they require relatively sophisticated ANN techniques. This is known as the temporal effect, and more advanced techniques such as finite impulse response (FIR) types of ANN and recurrent ANNs are being explored and developed to deal specifically with this type of problem. Real world examples of time series problems using ANNs include: · Foreign exchange trading systems: Citibank London [Penrose 1993, Economist 1992, Colin 1991, Colin 1992], HongKong Bank of Australia [Blue 1993]; 4 The company has since listed in the US stock exchange (NASDAQ:PPNT) under the trading name of PAPNET of Ohio. The PAPNET diagnosis program has recently been made available in Australia. Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 18 · Portfolio selection and management: LBS Capital Management5 (US$300m) [Bylinsky 1993] (US$600m) [Elgin 1994], Deere & Co. pension fund (US$100m) [Bylinsky 1993] (US$150m) [Elgin 1994], and Fidelity Disciplined Equity Fund [McGugan 1994]; · Forecasting power demand and determining electricity usage patterns for rate structures analysis for utility companies [Hample 1996]; · Gas detection with electrocatalytic gas microsensor technology [Comello 1996]; · Forecasting weather patterns [Takita 1995]; · Speech recognition network being marketed by Asahi Chemical [Nelson and Illingworth 1991]; · Predicting/confirming myocardial infarction, a heart attack, from the output waves of an electrocardiogram (ECG) [Baxt 1995, Edenbrandt et al.1993, Bortolan and Willems 1993, Devine et al., Baxt and Skora 1996]. Baxt and Skora reported in their study that the physicians had a diagnostic sensitivity and specificity for myocardial infarction of 73.3% and 81.1% respectively, while the artificial neural network had a diagnostic sensitivity and specificity of 96.0% and 96.0% respectively; and 5 LBS Capital Management Inc., is a Clearwater, Florida, firm that uses Artificial Neural Networks and Artificial Intelligence to invest US$600 million, half of which are pension assets. It has reported no loss year in stocks and bonds since the strategy was launched in 1986 and its mid-capped returns have ranged from 14.53% in 1993 to 95.60% in 1991, compared to the S & P 400 (sic), which returned 13.95% and 50.10% respectively. [Elgin 1994]. Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 19 · Identifying dementia from analysis of electrode-electroencephalogram (EEG) patterns [Baxt 1995, Kloppel 1994]. Optimization problems involve finding a solution for a set of very difficult problems known as Non-Polynomial (NP)-complete problems. Polynomial problems are problems, if given an appropriate algorithm, can be solved in some polynomial time. On the other hand, solutions to NP-complete problems are not easy to find, with no known mathematical formula or algorithm to determine the solutions. According to the Neuralware Manual [1991, p.14], the known solutions to this class of problems have computation time which increases exponentially with the number of inputs. In other words, the time needed to solve the problem cannot be bounded by a polynomial function of the inputs. Combinatorial-type problems can be either Polynomial or NP-complete, depending on the problem at hand. Examples of problems of this type include the traveling salesman problem6 , job-scheduling in manufacturing and efficient routing problems involving vehicles or telecommunication. An AI technique, called heuristic, is often used to find ‘good’ or ‘acceptable’ solutions for such problems. Determination of optimal solutions for this class of problems is almost always impossible. An example of a heuristic rule in the case of the traveling salesman problem, is to visit the nearest unvisited city from the current city. This rule is also commonly known as a variant of the “greedy algorithm”. The ANNs used to solve such problems are conceptually different from the previous two categories (classification and time-series), in that they require unsupervised networks, whereby the ANN is not provided with any prior solutions and thus has to ‘learn’ by itself without the benefit of known 6 The traveling salesman problem (TSP) is basically a problem whereby a salesman is required to visit N number of cities using the shortest possible route. Chapter 1: Introduction to Artificial Intelligence and Artificial Neural Networks CNW Tan Page 20 patterns. Statistical methods that are equivalent to these type of ANNs fall into the clustering algorithms7 category.