ARTIFICIAL INTELLIGENCE

Concepts and applications in engineering

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Edited by

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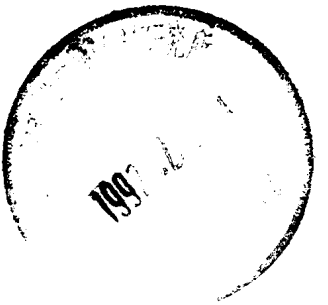

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Preface

In recent years, artificial intelligence (AI) has become a vibrant topic in the field of science. There have been many attempts to define AI but still no single definition has been given which adequately encompasses every aspect of the subject. Minsky defines AI as the task of making machines perform functions which, if done by human beings, would require intelligence. This then begs the question of defining intelligence. In general, intelligence is the ability to make primitive judgements by logical arguments. In nature, man is consider to be an intelligent organism because when faced with some information from his senses about the current environment he is capable of understanding the situation and selecting an appropriate course of action. Of course, in some cases this action may not be correct, but an intelligent human being would learn from his mistakes. With this in mind, we define AI to be the development of techniques which can be used to reproduce this ability in computers and other machines.

One product of AI is the development of expert systems and during the last 30 years many researchers have been working on the application of these systems to specific problems. In general, an expert system is a highly sophisticated computer program capable of making human-like decisions by representing the human expertise in the form of explicit rules. In traditional expert systems knowledge is represented in the form of fixed IF...THEN... rules, but researchers are now realizing that the human experts do not always make decisions in such rigid fashion. They also learn from experience by way of analyzing the consequences of previous decisions. Their responses may also be based on what is often described as "intuitive understanding" of the situation with no obvious analytical component. Therefore, recent years have seen a growing interest in development of computer programs that are capable of learning and synthesizing their own knowledge from previous

experience.

With AI advancing so rapidly, it is necessary to keep up with the new developments in this field in both theoretical and practical issues. The main objective of this book is to present the concepts and the principles of AI in a language understandable to engineers. It also gives representative examples of the way in which AI techniques are being applied in different fields of engineering.

The book is divided into two main parts. The first five chapters are devoted to the concepts and the principles of artificial intelligence and expert systems. The chapters also illustrate how the field of artificial intelligence has evolved over the last 30 years. The first chapter looks at expert systems from a historical point of view. The second and the third chapters cover some aspects in classical expert systems, ranging from architectures for expert systems to learning strategies. The subsequent chapters in the first part of the book present a number of techniques for the design of intelligent systems which implement the expert systems philosophy in different ways. These techniques include neural networks, pattern recognition and adaptive signal processing.

Part two of the book is entirely devoted to the applications of artificial intelligence. Here, intelligent and expert systems are described which have been applied to a number of problems in the field of communication, instrumentation, medical and sonar signal processing and speech recognitions. In each case it is shown how the concepts presented in the first part have been adapted for these specific problem areas. Although there is a electrical engineering bias in the selection of the applications, the chapters highlight many problems encountered when adapting AI techniques to a wide variaty of practical problems.

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Chapter 1 looks at artificial intelligence as a scientific discipline from the invention of the digital computer to the late 1980's. It illustrates the progress of the field as a whole by looking at some typical systems such as the Pandemonium, the Perceptron, WISARD, NETtalk, GPS, SHRDLU, MYCIN and EURISKO, each of which marked a change in the prevailing ethos of AI research. A number of selected commercial systems are used to illustrate the kind of work that is being done in this field. The chapter concludes with a look towards the 21st century and 6th generation computers.

Chapter 2 provides an introduction to the blackboard architecture and discusses issues that arise when designing or using systems with that architecture. In particular, issues of blackboard consistency, control strategy and system efficiency are considered. As an example of a blackboard architecture, the HASP system is described in detail. Some related technologies, such as chart parsing, assumption-based truth maintenance and dynamic databases, are also discussed. Finally, the strengths and the weaknesses of blackboard architecture are evaluated and some open research issues in this field presented.

As already mentioned, recent years have seen a growing interest in systems which are capable of synthesizing the knowledge of an expert. One way of achieving this is through the use of machine learning systems (MLS) and the rest of the chapters in this part of the book look at the theoretical developments in this field. The concept of machine learning, as a general area of research in the field of AI, is the subject of chapter 3. Here learning is formulated as a problem of heuristic search and the relationship between expert system methodology and inductive rule-learning is discussed. Two inductive systems, ID3 and AQ, are discussed in detail and the main limitations of these systems are highlighted. The extensions for including probabilistic classifications and fuzzy matching with rules are also mentioned. The chapter also describes some other learning techniques which are more suitable to noisy data. The chapter concludes by outlining some current research and developments in the field of machine learning.

Another form of learning involves the use of neural or connectionist systems. Neural networks offer an alternative approach to building intelligent systems and chapter 4 studies multi-layer perceptrons (MLP) which are one of the most widely used neural network architectures. The chapter describes the back-propagation algorithm used to train MLP. The performance of this algorithm depends on a number of parameters such as the network complexity (i.e. number of nodes), the adaptation rate, momentum and also the presentation of the training examples. The effects of these parameters on the performance of the network are investigated by looking at an artificial problem: the learning of the concept of a "right-angle triangle" by looking at the sides of a valid triangle. The chapter also reports on the performance of a MLP used for the classification of different types of back pain.

The last chapter in this part of the book reports on the development of a MLS which employs techniques from the field of pattern recognition and adaptive signal processing. Pattern recognition has been used for many years in different areas such as weather

forecasting, hand-print character classification, speech recognition, medical signal and image processing, remote sensing and satellite image interpretation. Similarly, adaptive signal processing has been used in different areas of communications such as channel equalization and modelling, echo cancellation and voice coding. This chapter illustrates how these two techniques are combined for the design of intelligent systems. The chapter gives an introduction to pattern recognition and classification using multi-dimensional discriminant analysis methods. It also reviews and compares a number of adaptive algorithms which can be used as a learning strategy for a class of adaptive architectures, namely the linear combiners. Finally, the chapter describes a data analysis program developed to improve the performance of the linear combiners by providing information on the relationships between the inputs and the outputs of the system under observation.

The first chapter in the second part of the book illustrates the application of AI techniques to improve spectral estimation of signals in the restricted domain of biomedical signal analysis. Spectral estimation is one of the fundamental problems in signal processing and here a Prolog blackboard shell is used to estimate the correct autoregressive model order for the best performance. This estimation technique is then used to track the fundamental frequency of real foetal heart signals.

Chapter 7 is devoted to the application of expert systems for the estimation of systolic time intervals of foetal heart sounds. The systolic time intervals are often used by doctors and obstetricians to decide on the well-being of the foetus before birth. In this approach a combination of conventional signal processing and rule-based reasoning is adopted to form "solution islands" n areas of good signals and these islands are joined making maximum use of a *priori* knowledge of foetal heart rate behaviour. A proposal is outlined for intelligently combining the information from three different types of tranducer in order to automate the process of measuring these intervals.

Sonar interpretation is the subject of chapter 8. For many practical applications, sonar interpretation involves detecting and describing objects such as pipelines, divers and underwater vehicles. It may also involve analyzing image textures to describe different geological strata such as sand, rocks, shingle and oil. A human expert working with sonar data seems to use two levels of processing. First, he subconsciously performs image segmentation to identify the characteristic features and he then uses rule-based reasoning based on his a *priori* knowledge of the environment. To automate this task a blackboard system, BOFFIN, has been developed. This is described in

detail and the chapter illustrates how different stages of the interpretation process can be carried out using this system. Finally, the system is evaluated by looking at the performance of BOFFIN on real sonar images.

Automatic speech recognition (ASR) is one of the most challenging problems in the field of AI. Chapter 9 looks at some of the important aspects of ASR problem and briefly reviews two of the established approaches to ASR, which are called the strong knowledge (conventional symbolic AI) approach and the strong algorithms (stochastic models) approach. The connectionist (or neural network) approach to ASR is considered in more detail. The chapter summarizes the strengths and weaknesses of variations on the error back-propagation technique for multi-layer perceptrons (MLP). It also compares the performance of the MLP with that of a hidden Markov model (HMM). The performance of the MLP is not as good as the HMM, but in the author's view a successful marriage of different approaches will be part of the developments in ASR in the future.

At production level in industry there is a general need for built-in monitoring systems which can automate the process of fault diagnosis and calibration for final quality testing. Traditionally, the fault diagnosis and calibration have been carried out manually by skilled operators. This approach is very time-consuming and expensive and in recent years intelligent systems have been employed to carry out these tests. Fault diagnosis and calibration are the subjects of the last two chapters in this book. First, in chapter 10, the fault diagnosis of 16-QAM (quadrature-amplitude-modulated) digital radios is considered. Two approaches are investigated, these includes a rule-based expert system and the machine learning system described in chapter 5. The performance merits of both systems are highlighted and the drawbacks are also detailed. This comparison leads to the proposal for a hybrid system, using a combination of both approaches.

Finally, chapter 11 details the problems in applying a machine learning system to the alignment of waveguide filters. The MLS, described in chapter 5, is adapted in such a way that it can assist an unskilled operator to perform accurate and fast tuning of these filters. Issues such as feature extraction and methods of training the system are discussed. The chapter also highlights many practical problems encountered due to the physical structure of the filters and suggests a number of methods for improving the performance of the intelligent tuning system.

This book cannot offer answers to all the problems faced by engineers in designing intelligent systems nor can it provide examples of applications of AI in all the engineering disciplines, but the contributors, who are drawn from industry and leading AI research centres in UK, have identified some of the main difficulties that have arisen in the design of expert and intelligent systems and illustrated how these problems may be overcome. It is therefore hoped that others will profit from our experience. The book can be used as a reference or a text book for those already engaged in AI and, in particular, those practising engineers who, while not specialists in AI, are interested in learning and applying AI techniques to their practical problems.

I am first grateful to all the authors for their invaluable time and the energy they have devoted to preparing their chapters. I am also grateful to Prof. Tom Crawford, Prof. Peter Grant and Dr. Colin Cowan for their support and encouragement. Thanks are also due to many colleagues in the signal processing group in the Department of Electrical Engineering at the University of Edinburgh, in particular, Dr. Mulgrew and Dr. Gibson.

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