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Book Review

MULTISTAGE FUZZY CONTROL: A MODEL-BASED APPROACH TO FUZZY CONTROL AND DECISION MAKING, by Janusz Kacprzyk, Wiley, Chichester, 1997, x + 327 pp., ISBN 0-471-96347-X (Hardcover, £45).

The work reported in this book represents a very significant advance in the application of fuzzy methods to control, as is emphasised in an enthusiastic Foreword by Lotfi Zadeh, the originator of fuzzy techniques. Fuzzy methods have been applied to control previously, but usually with the aim of imitating the actions of a human expert controller. The human controller describes his control policy using the imprecise linguistic terms that are usefully represented by fuzzy set membership, so fuzzification of an 'expert system' approach is an obvious step. Controllers using fuzzy logic have been incorporated in cameras and in such things as washing machines and other domestic electrical appliances.

An approach that imitates a human controller will not, unless by accident, improve on the performance of the human, and will not adapt automatically to changes in the controlled system. The new approach is model-based, as the title of the book indicates, in that it uses a model of the system to be controlled, and an optimal control policy is derived. In order to allow the representation of fuzzy systems by sets of "IF . . . THEN . . ." assertions (or production rules), a precise meaning is attached to such rules with fuzzy entries for both the condition and he consequence. The method adopted is known as the Mamdani implication (even though, as the present author observes, it is not, strictly, an example of implication as understood in formal logic).

Goals and constraints are also expressed in terms of fuzzy set membership, and the meaning of a fuzzy event is compared to that of a stochastic event. As is suggested by the reference to multi-stage decision making, the treatment uses principles of dynamic programming, in a fuzzy version, as well as the operations research principle of branch-and-bound.

In a lengthy second chapter (47 pages) basic elements of fuzzy sets and fuzzy systems are reviewed. This chapter is actually more comprehensive than is necessary for understanding of what follows it. Extra detail has been included for the sake of completeness and to allow for subsequent developments in the control schemes described later. The chapter is, in fact, an excellent introduction to the subject-area and could stand alone as a teaching text.

The author is well aware that some parts of the introductory chapter, like other introductory material elsewhere, become somewhat tedious as numerous alternative versions of functions or manipulations are listed, without, at least initially, any indication of reasons to choose between them. For example, *t-norms* and *s-norms* (having some correspondence to intersection and union of fuzzy sets) are described in considerable variety, as are some other operations. The author makes the perceptive comment: ". . . this abundance is often an obstacle to a more pragmatically inclined user to whom the real merit of an operation is its usefulness (adequacy) and not nice formal properties".

The comment may give a feeling for the erudite and yet mildly-chatty style of presentation, which makes this an admirable introductory text.

In the third chapter a general setting for multistage control under fuzziness is developed, and in the next four chapters refinements and developments are treated. The process model is always of a discrete-time form (as usually assumed in Dynamic Programming) and the treatments in the four chapters termination time of the process. The termination time may be fixed and specified, implicitly specified, fuzzy, or infinite. The termination time is implicitly specified when a terminal state, or set of states, is specified. In the context of processes with a specified termination time, methods using neural nets and genetic algorithms are described.

The new approach is justified by reference to a variety of applications. All of them have a 'soft' character which means they are not amenable to standard non-fuzzy methods. That is to say, at least some of the constraints and goals, and input data to the controller, cannot be specified in precise numerical form. Instead they refer to such imprecise considerations as severity of flood damage, quality of a public amenity, and, in one example, a physician's impression of some characteristics of a patient under anaesthesia.

Specific applications that are discussed in a fair amount of detail include socioeconoimic regional development, flood control in a water resources system, research and development planning, the scheduling of generation unit commitment in a power system, and intra-operative anaesthesia administration. General application areas that are treated are resource administration and inventory control.

A number of other applications are introduced very briefly, allowing the interested reader to find details in the literature quoted. One that has direct relevance to practical robotics is the scheduling of autonomous guided vehicles in flexible manufacturing systems. The fuzzy approach allows this to be with respect to such things as expected congestion level and collision danger along respective routes, and the condition of the travelling surface. These are certainly considerations that a human driver takes into account in route-planning.

The book has an impressive bibliography. It is well presented and is an important contribution breaking new ground.

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CONTROL THEORY OF NONLINEAR MECHANICAL SYSTEMS, by Suguru Arimoto, Clarendon Press, Oxford Science Publications, Oxford, UK, 280 pages incl. index and appendices (£55)

Despite the generality of the title, this book concentrates primarily on Manipulator Robotics and should be of interest to the general readership of this journal. There are, however, a number of flaws in the presentation which render the book unnecessarily obscure.

I found the introductory chapter to be quite readable, where the author focuses on Newtonian mechanics in the development of robot kinematic and dynamic models. I enjoyed the different interpretations given to familiar equations and found the historical notes at the end of the chapter very useful [although subsequent historical notes tended to degenerate into a 'who got there first' listing]. Other aspects of note in the first few chapters include specific inclusion of actuator dynamics in the general dynamic equations, a subject frequently glossed over in robotics texts, and the comparisons of different control schemes.

However, I became somewhat frustrated by the stark contrast in explanation of certain fundamentals. The author goes to great lengths to explain elementary physics, for example Newton's three laws, work power relationship, kinetic energy, yet assumes a *working* knowledge of vector calculus.

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found it impossible to gain any new understanding of some of the more fundamental concepts used in the book – especially that of Passivity.

Arimoto subtitles the book as a "passivity-based and circuit theoretical approach". The term is first introduced chapter 2 by stating that a previous equation (an integral of the generalised velocity vector times the control vector) "demonstrates the passivity of robot dynamics". How so? A reader, unfamiliar with the concept of passivity, would not gain any insight from this introduction. This is compounded by the following two mentions, one of which refers to a complex equation where "[passivity is naturally observed]", and the other a schematic block diagram representation of the robot where "it is easy to see [Figure] satisfies passivity". Such comments only serve to alienate the general interested reader.

My overall view is that this book would only be of interest to those who have already established a strong prior knowledge in the field, or to posgraduate researchers as an supplement to any introductory material.

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AN INTRODUCTION TO ARTIFICIAL INTELLIGENCE, by Janet Finley and Alan Dix, UCL Press, London, 1996, 276 pages, including index and bibliography (£14.95).

Introductory texts to *AI* are always too short and too theoretical; this book is very short. It covers all the main points of *AI*, discussing them by traditional area, and it also introduces neural networks and (the current fashion) multi-agent systems. All of the standard stuff is there: game playing, planning, natural language, vision, learning, and so on; the book ends with a couple of speculative chapters on theoretical and philosophical issues.

Although the material provides an introduction, that is all that it does; it does not go deep. Nor do the authors try to connect the various aspects of *AI* into a central theme; their theoretical chapters fail to convince.

This is an old-fashioned book in form and scope. It introduces *AI* in the way that would have been adequate about twenty years ago.

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COGNITION ET SYSTÈME, By Robert Vallée, Interdisciplinaire, Lyon, France, 1997, 136 pp. (F.F. 195).

This book's pithy text is the equivalent of hundreds of pages of more opaque and less focused writing. The author's style is compressed yet still retaining communicational clarity in the best Gallic tradition.

There is a great paucity of books on the general theory of robotics, although the field is overrun with technical byways. It is time that the forest be less hidden by the trees, and though the words "robot" or "robotics" do not appear in the text, any worker in the field will recognize the book's immense and unifying value. Aside from the apparatus of a good index, detailed *table des matières,* and excellent bibliography, its key ideas and their exposition all place this work in the region of select wheat in the latter twentieth century's plethora of chaff – a foreseeable by-product of the development of communicational technology *ipso facto.* In happy exception, in these pages are both useful mathematics and enlightening exposition.

We will be brief and to the point, since the reader can do no better than go to the book itself. We sincerely hope that an English translation will be forthcoming for those who do not read French. For those who do, the author's presentation is a delight of *multum in parvo.*

There is first a concise yet remarkably thorough history of the thinking and work that constitutes the core of cybernetics and systems theory. Then follow 12 sections on the processes of perception in a context of dynamic interchange with the environment. It should be carefully noted here, that this entire development applies very nicely also to robotic perceptive processes and their facilitation. This becomes clear in the next division of the book where there is a culminating discussion: In the dynamic context of interchange between a cybernetic system, being, or robot and the interacting environment – the artificial separations between perceiving, deciding and acting break down and a full-fledged dynamic symbiosis is revealed.

The author's great contribution here is his clearly delineating how these underlying truths may be applied to robotic design, resulting in far more human, and hence pragmatical useful robotics than we have seen. He well explains his neologism of epistemo-praxeology as a synthesis of the perceiving, deciding, and enacting of a given cybernetic system in symbiotic context with the given environment. The program introduced in this small but seminal book may well herald the hallmark of the robotics of the 21st century.

C. Musès