Robotica (2004) volume 22, pp. 345–349. © 2004 Cambridge University Press
Printed in the United Kingdom

Book Reviews

DOI: 10.1017/S0263574704210438

MOBILE ROBOTICS: A PRACTICAL INTRODUCTION, 2nd Edition, by Ulrich Nehmzow, Springer, London, 2003, ISBN 1-85233-726-5, xvi + 280 pp. (Pbk, £29.50).

Apart from the updating of references and Internet links this second edition differs from the first (reviewed in *Robotica* **18**, Part 2, p. 221, 2000) in having an extra chapter on the topic of Novelty Detection. (The increase in content is rather greater than indicated by the difference in numbers of pages, from 243, because the pages are larger in the new edition.)

The innovative nature of the contents of the book, in either edition, is not immediately apparent from the title or cover picture nor from a quick flick through the pages. It contributes, as the notes on the back cover claim, to a cutting-edge research topic. It is a pity that the title does not hint at this by the inclusion of some such term as "adaptive" or "viable". It introduces a new approach to mobile robotics aimed at the achievement of animal-like robustness and versatility.

In the new approach, sensors and actuators are integrated more closely than they would be in schemes based on traditional *AI*. It is acknowledged that this tighter linking of perception and action must be at the expense of complexity, but with the hope that the "intelligent bit" will arise as a result of interaction between various relatively simple processes, constituting an "emergent phenomenon" or "synergetic effect".

In the new edition, the twelve case studies of the first are supplemented by one more, and show ways of achieving an impressive repertoire of kinds of learned behaviour, navigation and mapbuilding. They are interesting not only from the point of view of robotics applications but also for their comparison with similar performance in animals. They employ an intriguing range of biologically-inspired techniques, including the self-organising feature map (SOFM) due to Kohonen.

The new chapter on "novelty detection" stems from a Ph.D. project and again makes ingenious use of the SOFM principle. Novelty detection is interesting from several points of view, one being that in small mobile robots the complexity of information processing and storage should be moderate and it is likely that attention to novelty detection will show ways of whittling down sensory data while preserving its important aspects. Also, there are tasks, of a surveillance or fault-monitoring nature, where novelty detection is just what is needed. An example that is considered in the book is the exploration by a small robot of a network of underground pipes, probably sewers, to detect anything abnormal. The experiments have been done with a robot traversing corridors in a building but it is argued that the tasks are essentially similar.

An immediate problem is that a system cannot be trained to recognise novelty, which may take many forms, so the training has to be in recognising normality, after which anything that deviates sufficiently should be reported. In some earlier schemes the significant amounts of deviation have to be set manually, but in the scheme described this has been avoided by modelling the phenomenon of habituation in living systems.

The book is an admirable introduction to its modern approach to mobile robotics and certainly gives a great deal of food for thought. At present the concrete results are limited to navigation and simple tasks of box-pushing and floor cleaning, and now surveillance and fault-monitoring, but it is easy to feel that there is the potential for very much more and that we are being given a glimpse of principles for future animal-like and humanoid robots, even though the author acknowledges that the main applications in the immediate future are likely to be in intelligent toys. Like its first edition, this is an important and thought-provoking book.

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DOI: 10.1017/S0263574704220434

ADAPTIVE MODELLING, ESTIMATION AND FUSION FROM DATA: A NEUROFUZZY APPROACH, by Chris Harris, Xia Hong and Qiang Gan, Springer, Berlin, 2002, hardback, xvi + 323 pp., ISBN 3-540-42686-8 (79.95 Euro).

This is an account of a major development by a research group in Southampton University on the extension of adaptive techniques to nonlinear and nonstationary environments. Adaptive control in the linear case is accepted as being completely solved. There have been previous attempts to extend the linear theory to the nonlinear case by locally-based linearisation, but it is claimed in the Preface that these are not very useful in practice. The difficulty arises even with control situations that are readily observable and well understood and where a human operator may be successful with only experiential knowledge.

New approaches to nonlinear modelling and optimisation were opened up by work on artificial neural nets, and also by development of fuzzy techniques. The present book describes means of combining these two and so producing solutions that have been applied in fairly simple situations but that tend to become impractical on scaling-up, an effect that has been termed the "curse of dimensionality". Much of the book is concerned with attempts to overcome this limitation.

Both neural-net and fuzzy techniques stem in the first place from biological observations, the former of phenomena at the single-cell level, and the latter of human linguistic performance, where a reference to, for example, a tall man, is understood even though "tall" is an imprecise term. The combining of the two might appear to suggest that fundamental neural action had been linked to overall behaviour at the linguistic level, but of course neuroscience has not proceeded so far. The present book is not primarily concerned with neuroscience but with practical control algorithms and it undoubtedly confirms the value of the neurofuzzy approach there.

The emphasis on "data fusion" refers to the ability of the adaptive controllers to combine data inputs from diverse sources. The methods are related to Kalman filtering and to support-vector machines. There seems to be no doubt that this well-presented book is indispensable for anyone concerned with difficult nonlinear problems of control. Reference is made to applications by the authors and their colleagues in the following areas:

- Submersible vehicle modelling and control.
- Gas turbine modelling and fault detection.
- Car driver and driving modelling.
- Obstacle detection and collision avoidance for cars.
- Missile tracking and guidance laws.
- Car engine torque modelling.
- Ship tracking, guidance and control.
- Ship collision avoidance systems.
- Helicopter collision avoidance system.
- Processing property relationships of aerospace materials such as aluminium alloys.

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DOI: 10.1017/S0263574704230430

IMMUNOCOMPUTING: PRINCIPLES AND APPLICATIONS, by A. O. Tarankov, V. A. Skormin, and S. P. Sokolova, Springer, New York, 2003, hardback, xi + 193 pp., ISBN 0-387-95533-X (£44.00).

This is an exploration of the possibility of basing new computing strategies on the immune system of the body, in something the same way as artificial neural nets have become an accepted technique.

It is argued that the immune system performs complex information-processing tasks, including pattern recognition and self-organisation, and is better understood than the nervous system. As these authors say in their Introduction:

> Actually, the immune system possesses not only memory, but is also able to learn, to recognise, and to make decisions about how to treat any molecule (antigen) even if that molecule has never before existed on Earth. Besides, the immune system defines the great diversity of possible molecular shapes in the highly individual context of its own experience, and it has developed strategies to free the genome from the task of straight-coding such diversity.

The requirement for pattern recognition requires the means of finding matching substrings within the strings constituting protein molecules or their analogues. This has been achieved by conventional computing methods in the search facilities associated with, for example, the human genome project. However, it is hoped that in an immunocomputer the result would be achieved in what seems to be the natural method. The data string represented by a protein molecule determines folding of the physical string in complex ways so as to arrive at an overall shape. Interactions with other molecules are, at least in part, determined by this shape.

It is suggested that there is here the basis of a negative-selection algorithm that would allow what is termed self-nonself discrimination of the kind that must underlie the body's immunological response. Reference is made to a project in New Mexico to protect a computer system by such means against unauthorised use, corruption of data files, and viruses.

In the second chapter the mechanics of protein folding, termed self-assembly, are analysed in considerable detail, depending on rather complex three-dimensional geometry. The spatial conformation of the protein is determined by the solid angle between successive bonds, and this, in turn, is partly determined by the types of atom bonded, but also has some freedom. The latter allows the molecule to settle to different forms, corresponding to energy minima, so that there is memory. The energy is affected by neighbouring molecules and there is recognition and either binding or repulsion.

The building blocks of an immunocomputer are formal proteins, or FPs, having similar status to formal neurons. FPs may be free or may be receptors of formal cells, corresponding to lymphocytes, and of two varieties, B-cells and T-cells. These are able to change their bindings and can either proliferate or die according to the bindings they form.

It is demonstrated that a computer formed of FPs and formal cells would allow pattern recognition and both supervised and unsupervised learning, and could be extended to language representation and knowledge-based reasoning. It would also have advantages in the modelling of natural and technical systems, and here reference is made to a paper[1] where the three-dimensional geometry that was invoked in connection with protein folding is applied to the folding, or draping, of cloth. The published paper includes only a passing reference to immunocomputing as such but is an interesting application of the general approach that is presumably relevant to many robotics applications.

Further possible applications that are discussed include, perhaps not surprisingly, some of an epidemiological nature, and others in the nature of security systems, including one to give advance warning of possible satellite collisions. A possible means of construction of an immunocomputer is described in considerable detail, and as with other biologically-inspired technologies, possibilities of closer association with living systems are explored. An immunocomputer could incorporate real cells and proteins, and might interact with the body as a diagnostic and remedial tool.

It is accepted that much of this is highly speculative at present, but the case for immunocomputing is nevertheless cogently and convincingly argued and this could be the start of a major development.

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Reference

1. A. Tarankov and A. Adamatzky, "Virtual clothing in hybrid cellular automata", *Kybernetes* **31**, Nos.7/8, 1059–1072 (2002).

DOI: 10.1017/S0263574704240437

EMBEDDED ROBOTICS: MOBILE ROBOT DESIGN AND APPLICATIONS WITH EMBEDDED SYSTEMS, by Thomas Bräunl, Springer, Berlin, 2003, hardback, xiii + 434 pp., ISBN 3-540-03436-6 (£54.00).

This is a detailed account of a very comprehensive and successful study of robotics, conducted mainly in the University of Western Australia but with acknowledgement of the participation of a number of other centres, in Canada, Germany, New Zealand and USA. The assistance of colleagues in various locations in writing the book is also acknowledged. The main development is a remarkably powerful controller, termed "EyeCon", that has been produced in a suitable form to be installed in quite small robots. When connected to a digital camera it is sufficiently powerful to allow on-board image processing, and it has the means of interacting with other sensors and actuators with high precision. It can run programs in *C* and *C*++, so complex robot behaviour is readily achievable.

The EyeCon controller itself, as well as associated hardware, and a variety of complete robots termed the EyeBot family, are available commercially from a company called Joker Robotics, with website: *http://joker-robotics.com*. The EyeBot family includes vehicles of various kinds as well as six-legged walkers, biped android walkers, and a flying robot. All the software mentioned in the book is freely available from: *http://robotics.ee.uwa.au/eyebot/*. This includes the operating system used in the controller, as well as *C* and *C*++ compilers to run under Windows or Linux, image processing tools, a simulation system and a large collection of sample programs. A large amount of teaching material including PowerPoint slides is available from the same source.

The title of the book is slightly ambiguous since it is not immediately obvious what is meant to be embedded in what. The intention is that a versatile controller is embedded in many different robots.

The various considerations are treated in remarkable detail. In the first Part of the book there are descriptions of various programming tools, and details of the inner working of the operating system, including its means of achieving multitasking with appropriate synchronisation depending on Dijkstra "semaphores". Sensors and actuators are treated, as well as the means of real-time image processing and a facility for wireless communication.

In the second Part various aspects of the design of mobile robots are discussed, including the various means that can be used to propel vehicles controllably. One of these is an omnidirectional drive. Balancing robots, walking robots and flying robots are also treated, as well as a simulator program.

The most remarkable part of the book is the third Part in which successful applications are described. They include maze exploration, discussed in the context of a "Micro-Mouse" international competition, and map generation, in which the robot has to explore and record a previously unknown environment which, unlike the test mazes that have been used, does not in general have all obstacles in a rectangular grid. Still more dramatic is the application of the principles to robot football, which is organised internationally in a number of different leagues. The most advanced league of all is that in which it is planned that humanoid legged robots should compete, but this is ahead of current technology. However, EyeBots have performed well in the next most advanced option where each wheeled player uses only data from its own sensors.

In preparation for two later chapters this Part has reviews of necessary aspects of artificial neural nets, genetic algorithms, and genetic programming. One of the later chapters then treats behaviour-based systems, following the lead of Rodney Brooks of MIT in linking sensors to actuators more directly than through a model of the environment. A robot using a neural net is described, able to learn to locate a ball and to drive towards it.

There is then a chapter that presents really impressive results in achieving legged locomotion, including the biped version. The control methods were evolved using genetic programming, once a suitable framework had been set up using splines to compute smooth trajectories. The numbers of trials needed for the evolution were such that they were performed using simulation rather than the hardware robot, but effective control seems to have been achieved surprisingly readily, considering the usually-assumed difficulty of the task.

Everything is presented in a pleasant chatty style, and with a remarkable amount of detail, so that, for example, the theory of splines is explained and there are even program listings to show just how they were computed. The quality of production is high, with numerous illustrations, some in colour. There is a very great deal here that anyone concerned with autonomous mobile robots will certainly want to peruse, irrespective of whether it is EyeCons or controllers of some other kind that are embedded.

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DOI: 10.1017/S0263574704250433

DIAGNOSIS AND FAULT-TOLERANT CONTROL, by M. Blanke, M. Kinnaert, J. Lunze and M. Staroswiecki, with contributions by Jochen Schröder, Springer, Berlin, 2003, hardback, xv + 571 pp., ISBN 3-540-01056-4 (£77.00).

There are many processes where overall failure would be expensive or even catastrophic and there is reason to use one of the techniques described in this book. A distinction is made between reliability achieved, expensively, by physical redundancy or simple duplication of facilities, and that achieved by analytical redundancy. In the latter the fault is diagnosed using a model and the controller is automatically redesigned so that the closed-loop system including the faulty plant satisfies the given specification. Model-based fault-tolerant control is a cheaper way to enhance the dependability of systems than traditional methods based on physical redundancy.

The above is of course an oversimplified picture, since the use of physical redundancy also requires some means of identifying the faulty component. It is also clear that means of achieving fault-tolerant operation should allow continued safe operation and not just a quick fix, and in fact the remedial action may be the means of averting catastrophic failure.

In the Preface it is claimed that the book introduces the main ideas of fault diagnosis and fault-tolerant control, including methods introduced in recent years. It is believed that this is the first work offering such coverage, with the further advantage of treating all the methods from a common viewpoint. Some of the material is in fact published here for the first time. One aspect of the common viewpoint is that all the methods are discussed in the context of two examples, one a simple tank system and the other a ship controller.

The tank example is very simple, with only two possible faults considered, and is obviously devised to be introductory. The example of the ship controller, however, refers to what seems to be a real problem in the navigation of bulk carriers and supertankers. In the final chapter a further set of applications is discussed. This includes a three-tank liquid handling system that no longer has the "toy problem" character of the introductory example. It also includes fault-tolerant control of a chemical process, and of a ship propulsion system, and of a steam generator. The chapter ends with a very comprehensive set of guidelines for implementation of fault-tolerant control.

Methods are described for the continuous-variable situation, and separately for operation with discrete variables, which can be appropriate where monitoring devices give discrete indications of aspects of plant operation. The hybrid situation where continuous variables are quantised by assignment to ranges is also treated. Familiarity with appropriate mathematics, and particularly control theory, is needed. Statistical considerations enter throughout, and the continuous-variable treatments invoke, among other topics, optimisation and Kalman filtering, while the discrete case depends on automaton theory. The reader is helped by summaries of the necessary mathematical theory in Appendices.

The four authors have respective affiliations in Belgium, Denmark, France and Germany and the book is the outcome of a project funded by the European Science Foundation between 1995 and 1999. The material stems from their work along with colleagues and Ph.D. students. A useful spin-off from the multinational origin is an Appendix listing the main technical terms with their equivalents in German, French and Danish.

It is rather surprising that there seems to be no connection with what would seem to be a related field, namely work on error-detecting and error-correcting coding in information transmission, recently admirably reviewed by MacKay.[1]

The book under review must clearly be unrivalled as the standard textbook and reference source in its field.

Reference

1. D. J. C. MacKay, *Information Theory, Inference, and Learning Algorithms* (Cambridge University Press, Cambridge, 2003).

DOI: 10.1017/S026357470426043X

INFORMATION THEORY, INFERENCE, AND LEARNING ALGORITHMS, by David J. C. MacKay, Cambridge University Press, Cambridge, 2003, hardback, xii + 628 pp., ISBN 0-521-64298-1 (£30.00).

This is a quite remarkable work to have come from a single author and the three topic areas of its title actually fall short of indicating its full breadth of coverage. The book is physically quite weighty, at just over 1.5 kg. The print size is smaller than usual, so there is a great deal of material here, even though the text is interspersed with numerous illustrations.

The author's aims in writing the book are explained in his Preface:

> This book is aimed at senior undergraduates and graduate students in Engineering, Science, Mathematics, and Computing. It expects familiarity with calculus, probability theory, and linear algebra as taught in a first- or second-year course on mathematics for scientists and engineers.
>
> Conventional courses on information theory cover not only the beautiful *theoretical* ideas of Shannon, but also practical solutions to communication problems. This book goes further, bringing in Bayesian data modelling, Monte Carlo methods, variational methods, clustering algorithms, and neural networks.
>
> Why unify information theory and machine learning? Because they are two sides of the same coin. In the 1960s, a single field, cybernetics, was populated by information theorists, computer scientists, and neuroscientists, all studying common problems. Information theory and machine learning still belong together. Brains are the ultimate compression and communication systems. And the state-of-the-art algorithms for both data compression and error-correcting codes use the same tools as machine learning.

A great range of topics is treated following this motivation, in a total of no less than 50 chapters and three appendices. The respective topics are interlinked and indications are given about which should be regarded as prerequisites for others, and which might be omitted in a first reading. Apart from the hierarchical or "prerequisite" links, however, there are others that have implications for the structure of the subject area. For example, the treatment of statistical inference is linked, appropriately, to learning in neural nets. The treatment everywhere is mathematical and getting to grips with it is a major task, but the author helps matters by writing in a chatty and often amusing style. In one of the reviewers' comments quoted on the back cover it is suggested that readers will enjoy the presentation so much that each will want to have two copies, one in the office and one at home for entertainment.

The treatment is specially valuable because the author has made it completely up-to-date. In particular, methods for error-detecting and error-correcting coding are described that are very new and can be considered state-of-the-art. Consistent with this aim of keeping abreast of developments is a large number of references to Internet sources, scattered through the text, as well as a large conventional bibliography at the end.

In spite of the author's care to integrate his topics, the book will certainly be useful as a source book for piecemeal reference, for example to the accounts of latest advances in error-correcting codes. Of the three appendices, one defines the mathematical notation used throughout, and the other two are entitled respectively: "Some Physics" and "Some Mathematics", and although they are quite short the book would be well worth consulting for these alone. The physics one gives an admirable discussion of phase transitions that underlie the Ising models of statistical physics, often referred to in connection with neural nets. The mathematics one gives admirable introductions both to Galois field theory and to linear algebra.

The book has seven Parts, of which the last holds only the appendices and each of the others has between four and eighteen chapters. Some idea of the topics covered is given by the six headings: (I) Data Compression; (II) Noisy-Channel Coding; (III) Further Topic in Information Theory; (IV) Probabilities and Inference; (V) Neural Networks; (VI) Sparse Graph Codes.

It can be seen that a wide range of topics relevant to cybernetics and to advanced robotics is covered. This magnificent piece of work is valuable in introducing a new integrated viewpoint, and it is clearly an admirable basis for taught courses, as well as for self-study and reference. I am very glad to have it on my shelves.

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DOI: 10.1017/S0263574704270436

INTRODUCTION TO EVOLUTIONARY COMPUTING, by A. E. Eiben and J. E. Smith (Natural Computing Series), Springer, Berlin, 2003, hardback, xv + 299 pp., ISBN 3-540-40184-9 (£30.00).

This is intended primarily as a textbook for lecturers and graduate and undergraduate students but will certainly attract a wider readership. The authors explain that each of them has many years of teaching experience, and has given instruction on Evolutionary Computing (EC) both in his home university and elsewhere, and they realised the need for a suitable textbook and decided to write this one. They have provided examples of practical applications in most chapters, as well as exercises for the student and suggestions for further reading. There is also a website from which teaching material including a PowerPoint presentation can be downloaded and used freely.

The basic ideas of neo-Darwinian evolution are briefly reviewed since they provide the inspiration for EC methods, but the emphasis is on practical computing and special stratagems are introduced as needed, irrespective of biological parallels. EC methods are characterised by being population based, so that a whole collection of candidate solutions are held and processed simultaneously, with some form of recombination to mix the solutions, and stochastic features expressed as random recombination and mutation.

The term EC is used to cover four "dialects" denoted by Genetic Algorithms (GA), Evolution Strategies (ES), Evolutionary Programming (EP) and Genetic Programming (GP). These operate on different kinds of population units, or representations. GA operates on strings of symbols from a finite alphabet, analogous to the genetic code, whereas ES operates on real-value vectors, EP on finite state machines, and GP on tree structures.

The power of the methods is demonstrated by the examples of applications described. Some of these may seem esoteric, referring to optimisation of specially-devised test functions, or the colouring of graphs, or the problems of placing eight queens on a chessboard so that none puts another into check, or learning to play checkers (draughts). Others, however, such as the "knapsack problem", can be argued to model a class of practical problems, and there are others again that are thoroughly practical, including scheduling and timetabling and modelling financial markets. A particularly convincing example is mentioned in the first chapter, where an irregular lattice structure that was designed using a GA algorithm is shown. Although it looks as though it was the result of being run over by a car it is vastly superior to a regular structure in an application where vibrations could be troublesome.

Although no specific examples are described it is observed that the methods are readily applicable to the "reverse engineering" type of problem that is a feature of numerous robotics studies.

Beside serving as an introduction the book is a guide to the state-of-the-art. One advanced topic is self-adaptation, whereby the adaptive process itself is improved adaptively. This is developed in connection with ES, which deals with continuous variables, and the adaptive improvements include the adjustment of step sizes and reorientation of axes in the test hyperspace. This has at least superficial similarity to considerations explored by Rosenbrock[1] on optimisation using a single operating point.

All the methods depend on specification of a fitness function to govern survival. The possibility of interactive operation where a human operator evaluates fitness is treated, with examples of evolutionary art so produced.

This is a well-produced and very useful book.

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Reference

1. H. H. Rosenbrock, "An automatic method for finding the greatest or least value of a function", *Computer Jnl.*, **vol. 3**, pp. 75–184 (1960).