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Book Reviews

Introduction to algorithms by Thomas H. Cormen, Charles E. Leiserson and Ronald L. Rivest. The MIT Press, 55, Hayward Street, Cambridge, MA 02142, USA, 1990, pp 1028, $49.50. Indian orders to: Affiliated East-West Press Pvt Ltd, 25, Dr Muniappa Road, Kilpauk, Madras 600010.

This is a well-written book on the subject by some of the most active researchers in the area of algorithms. Though it is intended for all levels of readers, from technical professionals to graduate and undergraduate students, it makes this field especially accessible to the undergraduate audience by the emphasis laid on clear explanations of the algorithms, provision of hand simulations, while retaining the mathematical rigour. The layout, characteristic of undergraduate books in the US, and the style and organization of the material are also excellent. At the same time, there is enough material here for an advanced course too.

The book is divided into seven sections: mathematical foundations, sorting and order statistics, data structures, advanced design and analysis techniques, advanced data structures, graph algorithms and selected topics. The first three sections are introductory and make the book self-contained. Mathematical foundations covers the various asymptotic notations, recurrences and their solutions, a brief survey of convergent and divergent series, some introductory material that is often covered in the first part of a discrete mathematics course (sets, relations, functions, graphs, trees, counting and probability). A comprehensive method of solving recurrences by the 'master theorem' is an interesting addition. The sorting and order statistics covers heapsort, quicksort, sorting in linear time by counting sort, radix sort and bucket sort and also the problem of picking the first, second,..., element in the sorted order. Analysis of running times is carried out in each case. The section on data structures first covers elementary data structures like stacks, queues lists, trees, hash tables and binary search trees. Some advanced topics like universal hash functions and analysis of randomly built binary search trees are also presented. Dynamic data structures are presented in the context of red-black trees rather than the customary AVL trees. Topics that are not typically covered in other books like dynamic order statistics and interval trees are also presented. Some guidelines on how to augment a basic data structure to support additional functionality is presented and an example is given by augmenting red-black trees to implement interval trees.

The advanced design and analysis techniques section covers dynamic programming, greedy algorithms and amortized analysis. The theoretical foundations of greedy methods using combinational structures known as 'matroids' are developed in a starred section. Though amortized analysis is a well-known technique for analysing certain algorithms, it has been treated here, perhaps for the first time, in a comprehensive fashion. The section on advanced data structures discusses B-trees, various mergeable heaps like binomial and Fibonacci heaps and finally the classical union-find algorithm for disjoint sets. The section on graph algorithms first covers elementary algorithms like breadth-first and depth-first searches, topological sort, strongly connected components and minimum spanning trees. Various shortest path algorithms and maximum flow algorithms are then covered comprehensively.

The selected topics section is the one that might interest the advanced reader most as many interesting topics are covered here. Three models of parallel computation are developed: comparison networks and combinational circuits followed by the most general PRAM model. There is a good introduction to the theory of parallel computation covering various PRAM machine models like EREW, CREW, etc., and some of the salient methods of parallel algorithm design like pointer jumping, prefix computations and Euler-tour techniques. It is also a good summary of the research work in this area that is available in a text-book form. Other topics that are covered are the various matrix operations, polynomials and FFT, number-theoretic (including a discussion of the RSA public-key cryptosystem, primality testing and integer factorization), string matching (with a good discussion on the Rabin-Karp, Knuth-Morris-Pratt and Boyer-Moore algorithms) and some basic computational geometry. The section ends with a discussion of NP-complete problems and approximation algorithms. Of these topics, the chapters on combinational circuits and matrix operations suffer by comparison with other chapters since those subjects have been competently treated in other books.

The book as it stands runs to 1028 pages and hence there must have been many topics that the authors wished to discuss but could not undertake to limit the size. Hence the following comments have to be taken in the proper spirit. One criticism that can be made is that there is no attempt to link algorithms to practical applications, for example, in areas like compilers, etc. Algorithms are typically treated in the abstract except in some of the problems. Given the wide variety of topics addressed, it would also have been appropriate to have discussed partial orders more extensively and covered fixpoints and their algorithmic complexity in some contexts, especially in dataflow analysis. It would also have been nice to have a discussion on some of the more recent results on perfect hashing and on interactive and zero-knowledge proofs. Finally, it would have been helpful to the student to have an outline of the solution to some of the starred exercises. These are but minor cavillings on a very well-written book that deserves a reputation enjoyed by some of the books of Knuth or Hopcroft and Ullman.

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Intensional logic and the metaphysics of intentionality by Edward N. Zalta. The MIT Press, 55, Hayward Street, Cambridge, Mass. 02142, USA, 1989, pp 256, $25. Indian orders to: Affiliated East-West Press Pvt Ltd, 25, Dr Muniappa Road, Madras 600010.

Intensional logics are formal systems for representing and explaining the apparent failure of four logical principles. They are: 'Existential' generalization, Existential generalization, Substitutivity, and Strong extensionality. Most of the intensional logics that have been developed handle the failures of just one or two of these principles. This book is concerned with an intensional logic that can be used to represent and explain the failure of all the four logical principles mentioned above.

The book is in five parts. Part I (Chapters 1 and 2) is an introduction to intensional logics and the proposed theory. The reader is assumed to have a good knowledge of modal and tense logics. Part II (Chapters 3–5) deals with strong extensionality. It also deals with a theory of relations and the language of encoding. It formalizes the notions of propositions, situation, world, and time, and also deals with rigid and non-rigid descriptions. The definition of 'world' appears to be circular. This is because the modal operator '$\Diamond$' appears in the definition of 'world' and semantic analysis of any formula employing '$\Diamond$' requires the notion of 'world'. In the proposed logic, every term of the modal language rigidly designates what it denotes. Such an interpretation does not agree with the intuitive understanding of 'world'.

Part III (Chapters 6–8) deals with the principle of 'Existential' generalization. It clearly identifies the two kinds of existence: being and existence. It deals with (i) formal representation of sentences about nonexistent and fictional objects, and (ii) use of these representations to explain the failures of 'Existential' generalization.

Part IV (Chapters 9–11) is concerned with substitutivity and existential generalization. The proposed logic is used to explain the failure of substitutivity and existential generalization in this part.

Part V (Chapter 12 and Appendix) establishes the superiority of the proposed logic over Montague's intensional logic. The Appendix describes the proposed intensional logic.

There are several novel and interesting ideas presented in the book. However, it assumes a good background in classical, modal, and tense logics. There is no motivation as to why K_t(tense) and S_5(modal) systems are employed by the author. Further, the bibliography provided at the end of the book is not exhaustive. The author lists down the axioms of (i) classical propositional and first-oder logics, (ii) modal logic S_5, and (iii) tense logic K_t. However, readers looking for more details on these logics are not provided with the relevant references. The relevant application areas of the proposed logic are also not clearly spelt out.

On the whole, this book is extremely useful for researchers in the area of intensional logic. Various formalisms concerned with the reasoning of abstract objects have been critically analysed and a novel and general intensional logic has been developed in this book. It will be of interest to researchers in the area of natural language processing also.

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Perspectives in control theory by B. Jakubczyk, K. Malanowski and W. Respondek (Eds), Birkhauser Verlag AG, Ringstrasse 39, CH-4106, Therwil, Switzerland, 1990, pp 352, SFr 118.

This is a collection of twenty-one papers presented at an international school held at Sielpia, Poland, in September 1988. A very brief account of the contents of the first few is as follows.

The first paper by Dirk Aeyels considers controlled o.d.e.s stabilizable by smooth feedback controls and shows that it remains so after adding an integrator. The result is known, but the proof is new and gives an explicit handle on the stabilizing control compared to the earlier proofs. Fattorini surveys the 'state of the art' in infinite dimensional maximum principle. Fliess proposes a new approach to linear and nonlinear realization theory based on 'differential algebra'. Geerts and Hautus give an up-to-date survey of the work on Riccati equation which crops up in linear-quadratic control problems. Hinrichsen and Pritchard study robustness ('stability margins') of linear feedback control systems under real and complex perturbation of the feedback transfer function. Jurdjevic studies a class of singular optimal control problems. Keviczky and Bokor give a comparative study of state space, matrix fraction and ARMA forms of stochastic realization theory for second-order processes. Kunisch studies parameter identification in elliptic systems. Kupka studies various aspects of 'Fuller's phenomena' whereby an optimal control problem leads to a bang-bang control with infinitely many switchings.

The list continues, but the foregoing should suffice to give a flavour of the scope of this conference. 'Control theory' has clearly been widely interpreted here to include allied topics such as identification, optimization algorithms and realization theory. At the same time, some branches of control theory (such as stochastic control) are underrepresented. The larger chunk is devoted to control of nonlinear o.d.e.s using geometric/algebraic methods and to control of distributed parameter systems. This is hardly surprising, as these are among the fastest developing frontiers of control theory. (see *e.g.*, the recent SIAM report *Future directions in control theory* edited by W. Fleming.) The nature of the papers varies from those illustrating a subtle technical point by examples to extensive surveys, from comparative studies of competing approaches to some pedagogically useful unification of scattered results and so on. Qualitywise, most appear to be competently executed though a few authors have perhaps palmed off their lesser results. The stronger point of this collection is the contributions of some of the leaders in the field, like Hautus, Jurdjevic, Sussmann, sharing their personal insights into subjects they have contributed much to. Also, for a conference organized in 1988, it has an impressive line-up of experts from the two sides of the now extinct iron curtain.

On the whole, a useful collection, though not indispensable.

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Weak convergence methods and singularly perturbed stochastic control and filtering problems by Harold J. Kushner. Birkhauser Verlag AG, Ringstrasse, 39, CH-4106, Therwil, Switzerland, 1990, pp 233, SFr74. Indian orders to Springer Books (India) Pvt Ltd, 6, Community Centre, Panchasheel Park, New Delhi 110 017.

The theory of weak convergence of probability measures can claim its antecedents to its most famous specimen, the Central Limit Theorem. The modern formalism of the theory, however, is not that old. It developed in the fifties due to the efforts of Soviet mathematicians, most notably Prohorov and Skorohod, with subsequent refinements by Varadarajan, Le Cam and others. The theory came of age with the appearance of two monographs, *Probability on metric spaces* by K. R. Parthasarathy (Academic Press, 1967) and *Convergence of probability measures* by P. Billingsley (Wiley, 1968), which remain its most cited reference works even today. Its impact on applied stochastic processes was almost immediate. This was but natural, since the probability distributions of random processes are what one usually has any handle on, the underlying 'probability space' being hypothetical. By introducing a not too restrictive convergence concept for these distributions and powerful criteria for its verification, the theory of weak convergence opened up a whole universe of weak existence and robustness results for stochastic equations as well as approximation results and limit theorems. To mention what is perhaps the most outstanding development it led to, one has the 'martingale formulation' of diffusion theory due to Stroock and Varadhan, now a cornerstone of modern theory of stochastic processes.

Prof. Kushner has been the most vocal advocate of weak convergence techniques among the 'systems and control' theorists concerned with stochastic systems. He successfully applied these techniques to existence theorems in stochastic control, approximation problems in stochastic control, asymptotic analysis of stochastic approximation algorithms and now to singular perturbations in stochastic control on which this book is based.

Before getting into the details of the book, let's take note of the other major technique of applied mathematics which it draws upon. This is the theory of singular perturbations, which may be considered to lie within the purview of 'averaging techniques' of mathematical physics. The latter refers to the situation where one approximates a composite system by a simple system by averaging out over the rapidly varying components. Examples are averaging over the fast modes (as in boundary layers), rapidly oscillating phase (as in stationary phase method) or finely distributed inhomogeneities (as in homogenization). Singular perturbations in stochastic systems are of two kinds. The first deals with systems with more than one time scale where one wants to average out the fast components. The second deals with situations where some ideal process featuring in the dynamics (such as 'white noise') is replaced by its 'perturbation' (such as 'wideband noise') which may be analytically less tractable (though perhaps physically more reasonable). The study of such problems dates back to the works of Khasminskii and others in the USSR, later refined by Varadhan, Papanicolaou and others in the USA. It is the latter techniques that Kushner brings over to stochastic control in this book.

The first three chapters constitute a crash course on weak convergence, stochastic processes and stochastic control, respectively, all at a quite advanced level, but lacking in much detail for obvious reasons. The next chapter describes singularly perturbed controlled stochastic differential equations and the associated control problems. This perturbation is in the sense of presence of dynamics on different time scales. Limit theorems characterizing the averaged systems and associated approximation results for optimal controls are established. The fifth chapter contains the analogous development for the average cost per unit time problem. This is qualitatively different from other problems because it is only the time-averaged ('ergodic') behaviour that matters here, not what happens in a finite interval, however long. The analysis here is based on the asymptotics of the functional occupation measures of the process, originally introduced by the present reviewer for studying existence results for such problems. Chapter 6 considers the equations of nonlinear filtering which are stochastic partial differential equations describing the evolution of the conditional distribution of the state given the observation process. Averaging and approximation results for these equations are presented. Chapter 7 outlines a specialized technique for proving averaging results called the perturbed test function method, which is used in Chapter 8 to prove limit theorems analogous to those of Chapters 4–5 for the other kind of perturbation, that due to 'wideband noise' in place of 'white noise'. Chapter 9 studies the stability of solutions to singularly perturbed stochastic differential equations using stochastic Liapunov functions. Finally, Chapter 10 concludes with a study of parametric singularities wherein the limiting behaviour of a fast component is better modelled as an additional noise term rather than an averaged quantity.

Needless to say, the book is highly specialized in its scope and extremely technical in its content. It does a good job of what it sets out to do, but its readership is likely to be confined to a small coterie of people working in such problems. For the benefit of any aspirants hoping to join the club, I would like to point out another related recent work by another leader in the field. This is *Perturbation methods in optimal control* by A. Bensoussan (Wiley, 1989) which covers similar issues but from a different viewpoint. The flavour here is 'analytic' (as opposed to the 'probabilistic' treatment of Kushner), relying on techniques such as asymptotic expansions rather than weak convergence. A serious student of the subject should study both.

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Set-valued analysis by J. P. Aubin and H. Frankowska. Birkhauser Verlag, CH-4010, Basel, Switzerland, 1990, pp. 461, SFr 125. Indian orders to Springer Books (India) Pvt Ltd, 6, Community Centre, Panchasheel Park, New Delhi 110017.

There was a time when a mathematician's vocabulary was dominated by words such as linear, smooth, well-posed, stable, single-valued and so on. The domain of their opposites, that is to say the likes of nonsmooth, illposed, etc., was largely left out. These seemed to lack enough structure to become elegant mathematics. Such a view these days would be a complete anachronism. The past few decades have seen tremendous advances in many of these hithertofore peripheral domains of mathematics, changing the complexion of mathematics (particularly applied mathematics) drastically. The most publicized of these is perhaps the theory of chaos and strange attractors which has made the following literary quip of Henry Miller come literally true: 'Chaos is a word we use to describe an order we have not understood'. A less publicized, but important in its own way, is the development in the twin domains of set-valued maps and nonsmooth analysis. This has been brought about largely by the exigencies of optimization theory, optimal control theory and game theory, not to mention the 'variational approach' to nonlinear differential equations. These subjects have it built into their nature that even reasonably simple-looking problems therein are already pushing the limits of conventional mathematics, bringing its limitations into sharp focus. Thus it is hardly surprising that this development has been spearheaded by researchers in these areas. There are enough results already to form a coherent picture of an emerging new discipline. One is thus tempted to adapt the above-mentioned quote of Miller to say that nonsmooth just describes the types of regularity that we have not quite understood.

With this background, the book under review is a well-timed introductory monograph on the subject. It is quite ecelectic in its coverage – the topics range from calculus of set-valued maps to differential inclusions. A chapterwise summary is as follows.

The first chapter introduces the basic calculus of set-valued maps, covering extensions of our usual concepts of limits and continuity. The second chapter considers closed convex processes, *i.e.*, set-valued maps whose graphs are closed and convex. This represents the correct generalization of linear maps in the conventional linear functional analysis insofar as many standard results of the latter (open mapping/closed graph/uniform boundedness theorems) have their natural extensions to this class.

Chapter 3 surveys some of the basic results of nonlinear functional analysis such as fixed point theorems, Ekeland's variational principle and the theory of monotone and maximal monotone maps.

Chapters 4 to 6 are devoted to the differential calculus of set-valued maps, extending the usual concepts of derivatives and associated rules (such as the chain rule) to this set-up. Chapter 6 is more specialized than the other two. The set-valued maps it studies are the epigraphs of real single-valued maps. The three chapters together cover the basics of nonsmooth analysis, an important offshoot of convex analysis that has had and continues to have tremendous impact on optimization and control theory.

Chapter 7 is a very brief introduction to the graphical and epigraphical convergence of maps. The extensions of this to more complex situations by de Giorgi, Attouch and others has been yet another major happening in nonlinear analysis and has been applied to several areas, including computer vision.

Chapter 8 surveys the 'measure and integration' theory of set-valued maps. Chapter 9 treats selection theory which deals with the issue of being able to make a pointwise selection from a set-valued map so as to get a single-valued function of prescribed regularity. Both are important topics from the point of view of optimal control and game theory. The same applies to the content of the last chapter, *viz.*, differential inclusions, which extends the concept of an ordinary differential equation by replacing the equality by a set inclusion.

As is evident from the foregoing summary, the book covers a broad spectrum of topics and is no match for a more specialized monograph in any of them individually (*e.g.*, *Optimization and nonsmooth analysis* by F. Clarke (Wiley, 1983), *Variational convergence for functions and operators* by Attouch (Pitman, 1984), or *Differential inclusions* by Aubin and Cellina (Springer, 1984)). Nevertheless, it will be hard to surpass the book in what it aims to be: an elegantly written, introductory overview of the field, with a near-perfect choice of what to include and what not, enlivened in places by historical tidbits and made eminently readable throughout by a crisp language. It has succeeded in doing the near-impossible—it has made a subject which is generally inhospitable to nonspecialists because of its 'family jargon' appear nonintimidating even to a beginning graduate student.

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Computation and control edited by Kenneth Bowers and John Lund (Progress in Systems and Control Theory Series), Vol. 1, Birkhauser Boston Inc., 675, Massachusetts Avenue, Cambridge, MA 02139, USA, 1989, pp 424, SFr 98.

This volume contains collection of papers which were delivered at the first Bozeman Conference on Computation and Control at Montana State University on August 1–11, 1988. The thirty papers presented in this volume dwell on both computation and control. The subject matters normally addressed in control theory such as intrinsic properties like controllability, observability, and stabilizability, and the other topics like feedback control, optimal control, and related numerical issues are addressed. The volume also contains papers on quasi-analytical and numerical techniques for solving the distributed parameter systems, and boundary-value problems encountered in optimization theory.

The problems on controllability and stabilizability are the twin issues which are studied with similar objectives in mind, *i.e.*, whether any realizable controller can be built for the system without making any major structural changes. Two papers on controllability and stabilization of nonlinear systems about certain operating point(s) fail to concentrate either on numerical issues or corresponding properties between original nonlinear systems and the linearized systems. The issues related to observability (which is dual of controllability) are discussed for parabolic systems with discrete observations, electrocardiography (dynamical system modelled by Laplace's equation) and chaos. These interesting papers also project many important questions that need to be answered before the distributed parameter control theory becomes a reality.

Over the past four decades, the regulation/stabilization of linear system is studied by the vast many. The same is not true with nonlinear systems. Isidori and Byrnes, two notable contributors in the field of nonlinear control theory, present methods of feedback design by extending classical frequency domain methods. Robust feedback stabilization of nonlinear systems deals with the two-time scale model, wherein the slower dynamics is not linearizable. Using the homotopy type of operator, feedback stabilization algorithm is developed. Feedback design is based on frequency domain approach. To satisfy tracking requirements, an additional dynamical controller driven by the error signal (difference between reference and measurement) is suggested. The simultaneous stabilization of linear time varying system is briefly analysed. This subject is currently drawing attention of many as it will have profound implications in future in aerospace systems, nuclear reactors, chemical industry, to name a few.

The determination of solution to two-point boundary-value problems arising out of optimal control theory and also to distributed parameter system are the most challenging tasks faced by any modern control engineer/scientist. Amongst the quasi-analytical methods, Galerkin's method, and collocation method are very popular because they try to minimise the error between actual and approximate solution in a least-squares sense. These make use of orthogonal or basis functions in obtaining the solution through discretization. Eigen functions are the special case of orthogonal function. On the other hand, the numerical techniques based on notably differencing techniques are developed mainly because these schemes are better suited for computer implementation. Here, improved accuracy is obtainable either by increasing the partitioning of the spatial and/or time domains into smaller blocks or by using a higher order nodal function. However, the trade-offs between these points to achieve better accuracy is not addressed in any of the papers presented in this proceedings.

It is well known that many standard control formulations can be undertaken in say, a, day's time, while the effort in getting the numerical solution may well run into a few months. The marriage of computation and control is, therefore, a welcome attempt on the part of the organizers of the Conference and editors of this volume. However, it is sad to note that many illustrations considered here have only academic value, since the emphasis is on mathematical finesse as against real-life representation of the problem. The book may be useful to persons who are already familiar with these topics for a reasonable period of time.

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Computational hydraulics – An introduction by Cornelis B. Vreugdenhil. Springer-Verlag GmbH and Co. KG, Heidelberger Platz 3, D-1000, Berlin 33, 1989, pp 200, DM 58.

The book *Computational hydraulics* by Cornelis B. Vreugdenhil has certainly a character of its own. Unlike other similar books where the reader's familiarity with the mathematical background of the underlying computational methods is assumed or provided separately, in this book, the mathematical theory is developed through simple examples of applications in different areas of computational hydraulics. The approach has its advantages and disadvantages. The advantage is the better physical feel that may be attained of the mathematical formulation and methodology. On the other hand, as the mathematical principles are distributed over several application problems, the uninitiated reader may fail to obtain a cogent picture of these principles. The book must be attractive to those who prefer to learn numerical modelling techniques through examples.

A lot of general conclusions regarding numerical modelling are arrived at heuristically from simple, specific problems. Another feature of the book is the fairly extensive discussions on accuracy and selection of step sizes in finite difference methods. But for a sketchy introduction to finite element method, the book is almost exclusively based on finite difference methods. Here again, explicit methods are covered in greater detail than implicit methods.

Sometimes computational hydraulics has been narrowly identified with solution of shallow water equations, but the book of Vreugdenhil covers a much wider range of problems including steady and unsteady ground water flows, solute transport, salt intrusion in estuaries, potential flows and boundary layers. The chapter on boundary layers is interesting because of the choice of applications. However, like most other chapters in the book, the level of presentation is kept simple. In fact, the subtitle of the book as well as Chapter 1 should caution the reader that the book is only of an introductory nature. Most of the computational problems dealt with in practice are much more complex than may be suggested by the presentation in the book.

In spite of the wide coverage, some areas have been left out, particularly pipe flow problems such as waterhammer. There are some editorial mistakes such as in reference to equation numbers, which might inconvenience the beginner. The book may be looked upon as a good familiarisation text in computational hydraulics.

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Current directions in computer music research edited by Max V. Mathews and John R. Pierce. The MIT Press, 55, Hayward Street, Cambridge, Massachusetts 02142, USA, 1989, pp 432, $ 35. Indian orders to: Affiliated East-West Press Pvt Ltd, 25, Dr Muniappa Road, Kilpauk, Madras 600 010.

This is a collection of articles on application of computers to music by pioneering research workers actively engaged in this field. The articles fall into a number of classes. There are set of articles which deals with synthesis of voices and rules for synthesis so that male or female singer could be mimicked by a computer. Another set of articles explain how to synthesise special characteristics of sound and music in particular and also articles on electronic VLSI models for synthesising various types of sounds. The question of simulating the performance of musical instruments and how it is done is discussed next. The issues on languages for representing music for a computer-based synthesis are discussed last.

An interesting feature of the book is an accompanying compact disk (with sound examples given in the text) and a videotape in which a concert has been recorded which uses electronic drums and violin. These are, of course, priced separately and cost $ 19.95 and $ 75 respectively.

All the articles are relevant only to Western Music. The basic contribution of this book is to explore in depth the nature of musical sound signals, both vocal and instrumental. This fundamental study is then used to synthesise various musical sounds, vocal and instrumental, using a digital computer. All the articles are by authorities in the subject and survey the field critically. This is an invaluable book for a researcher who is starting out in this area of application of digital processing in music.

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